THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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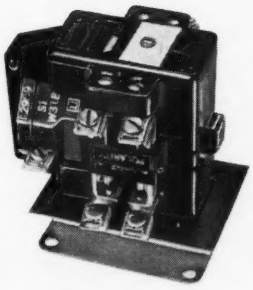

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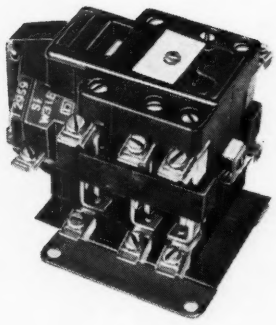

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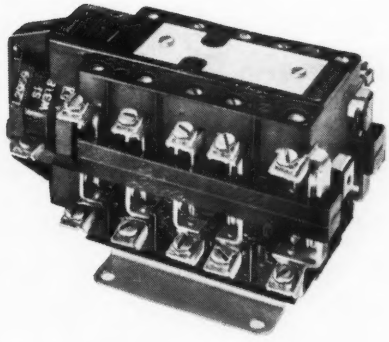

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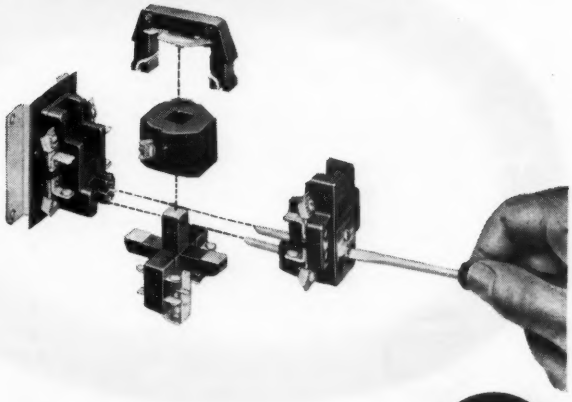

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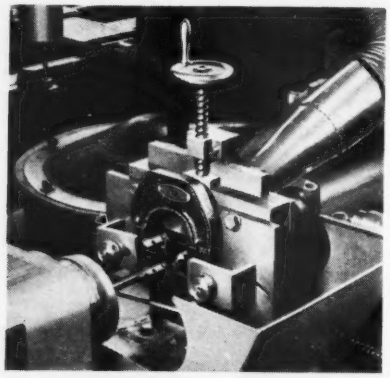

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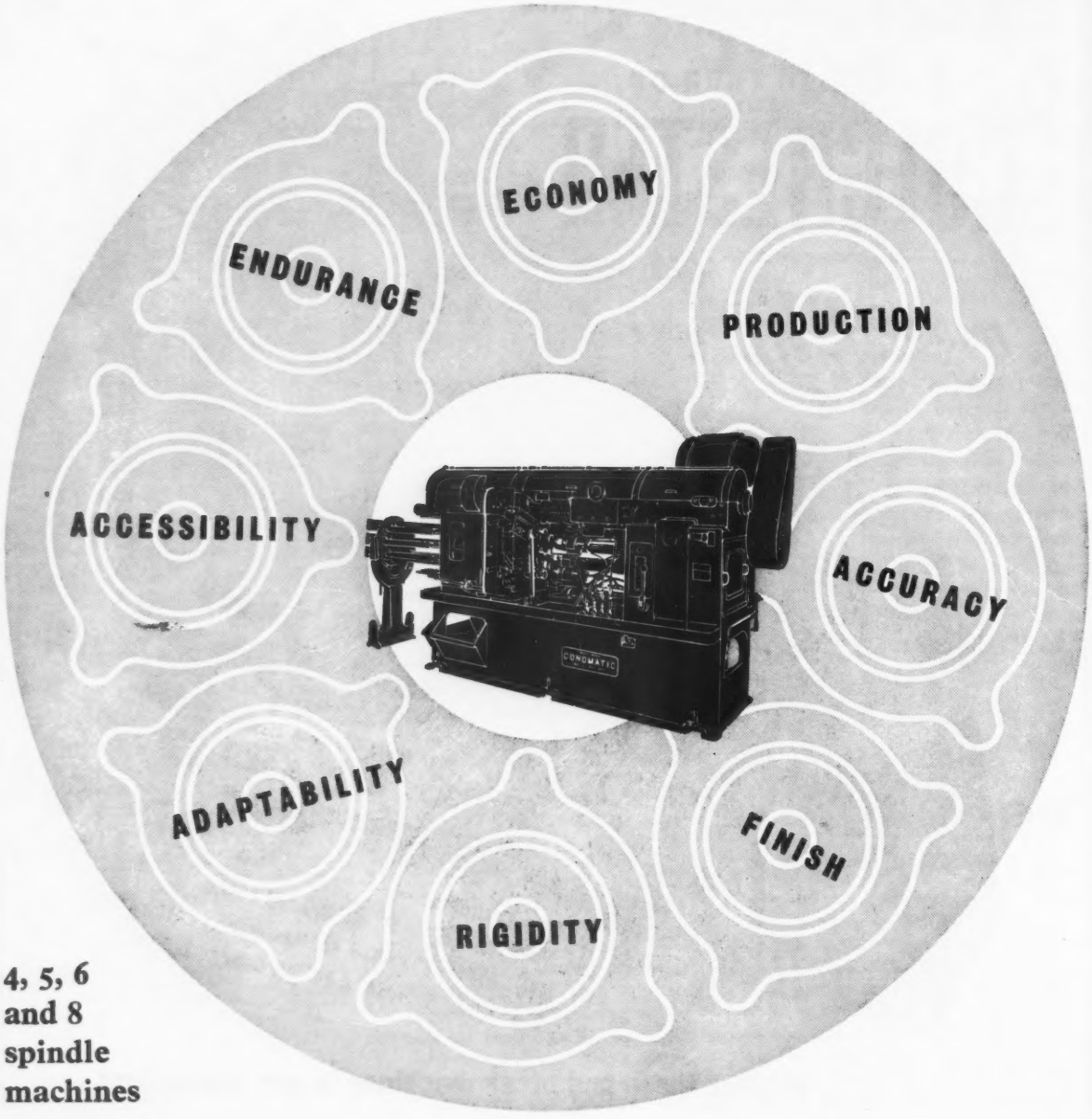

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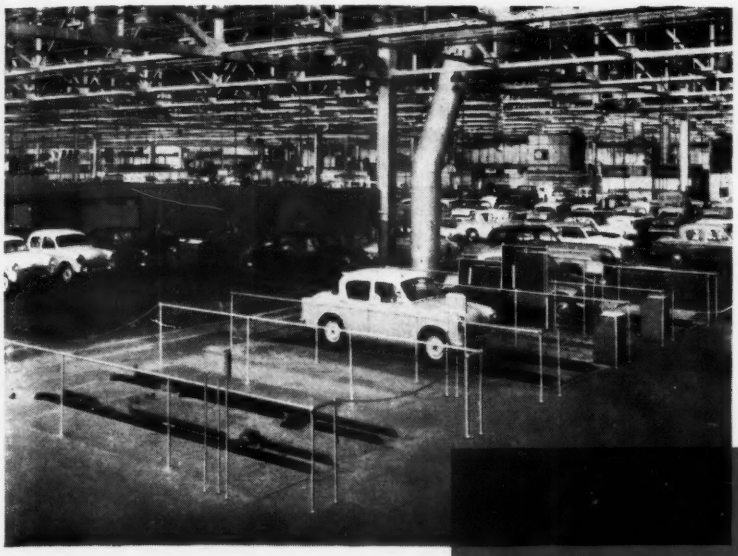

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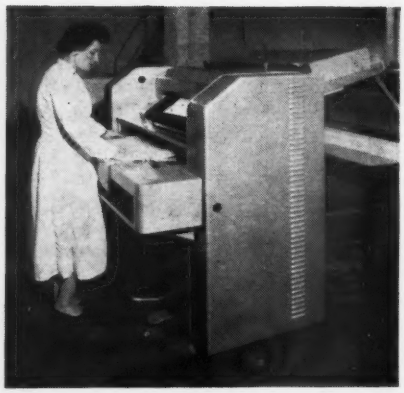

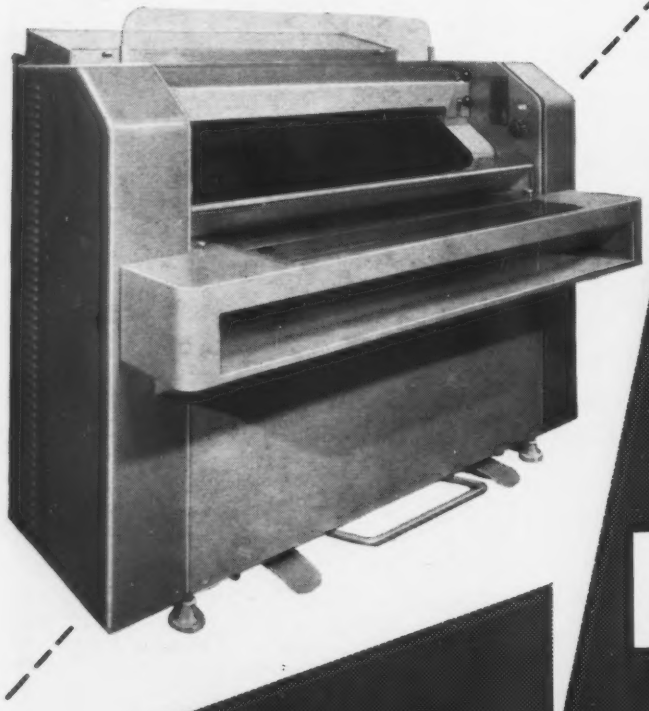

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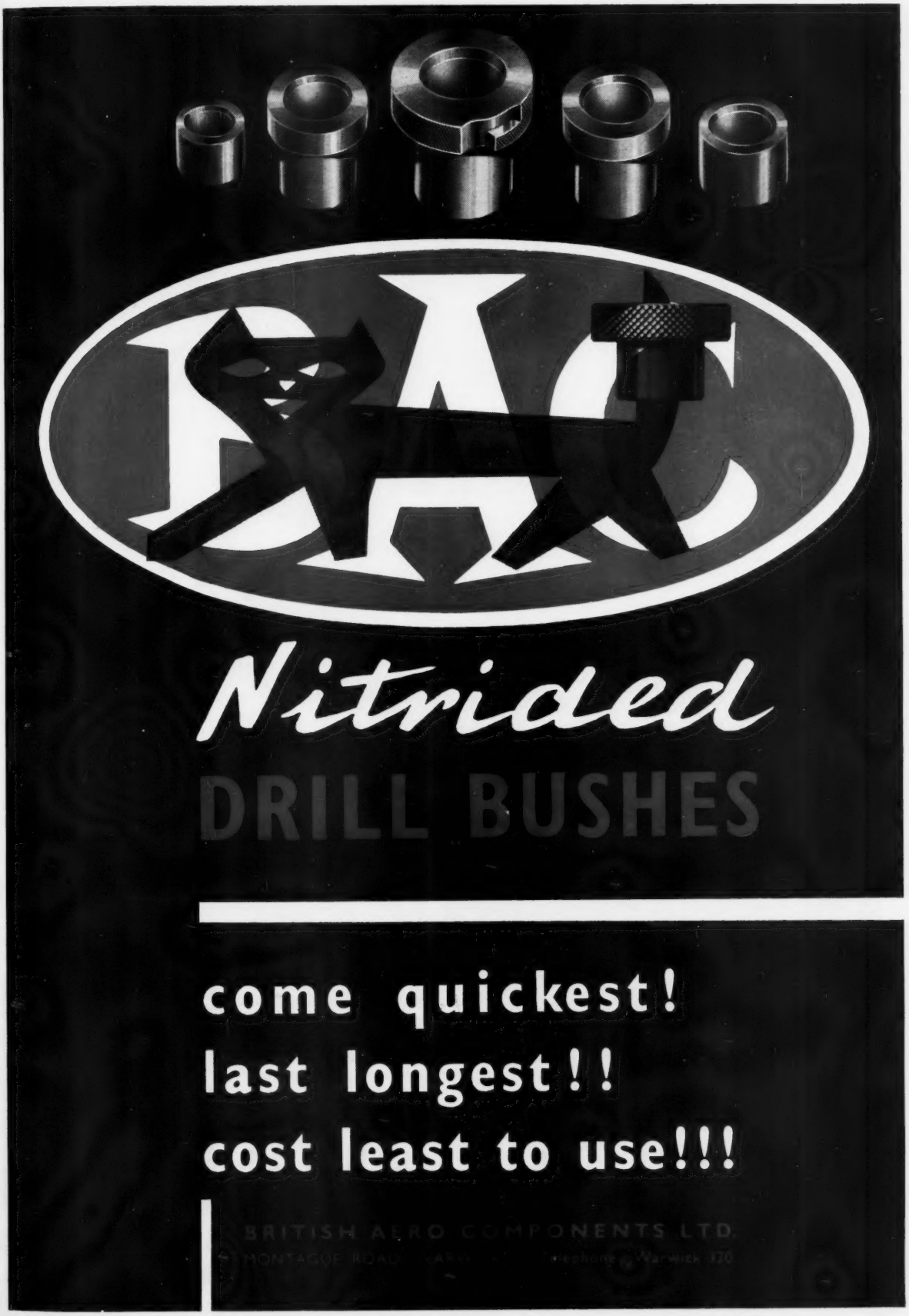
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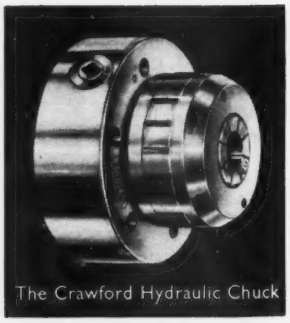
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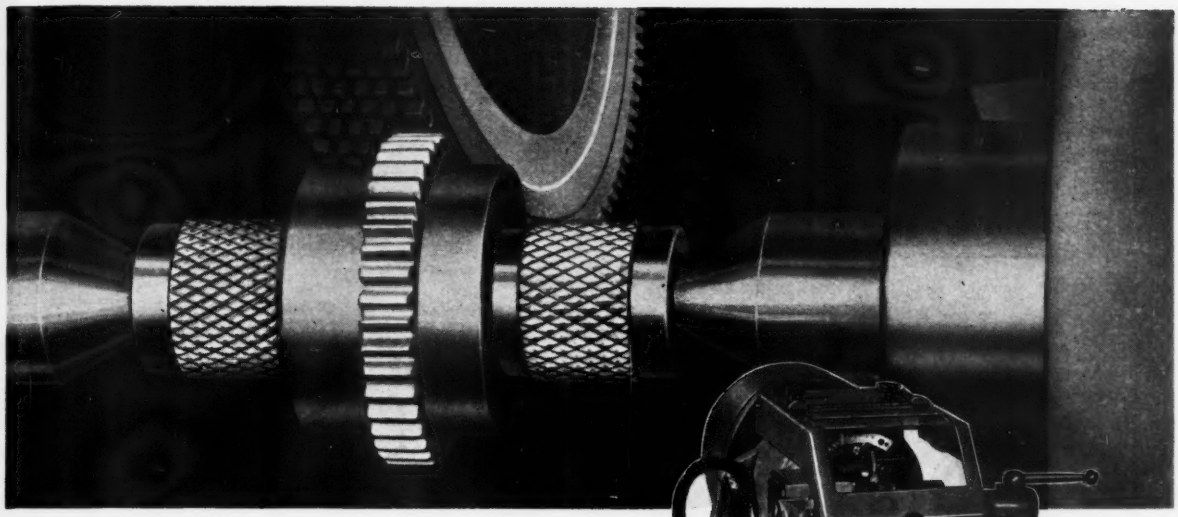

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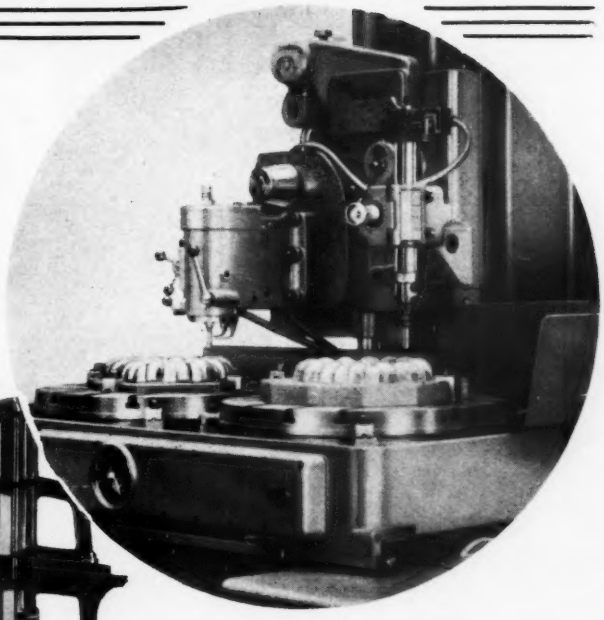

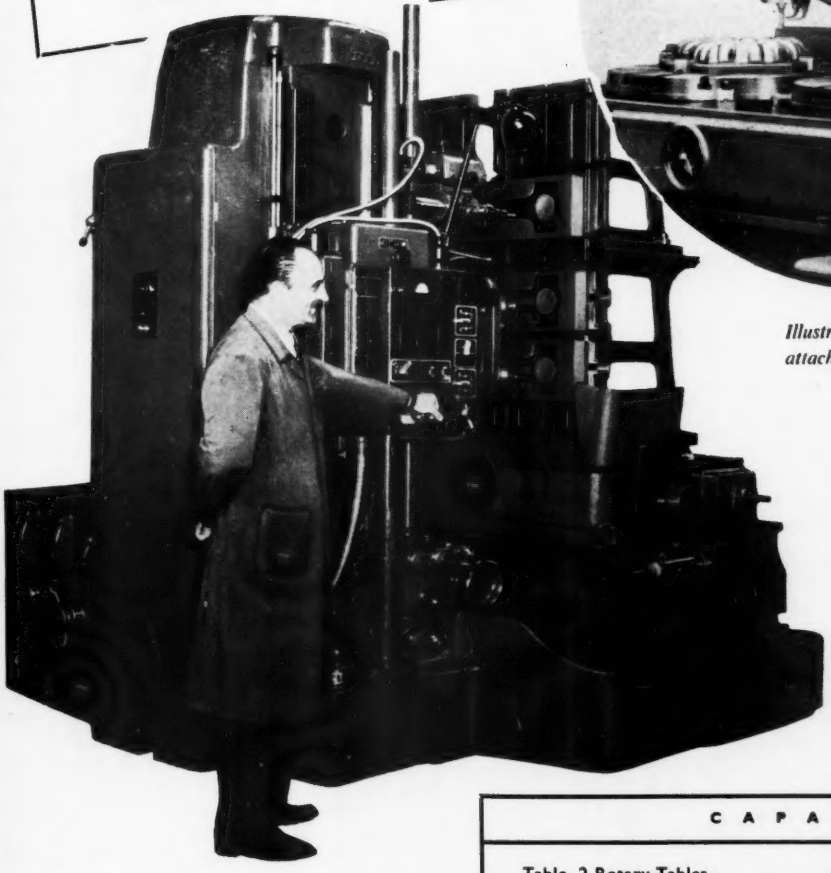

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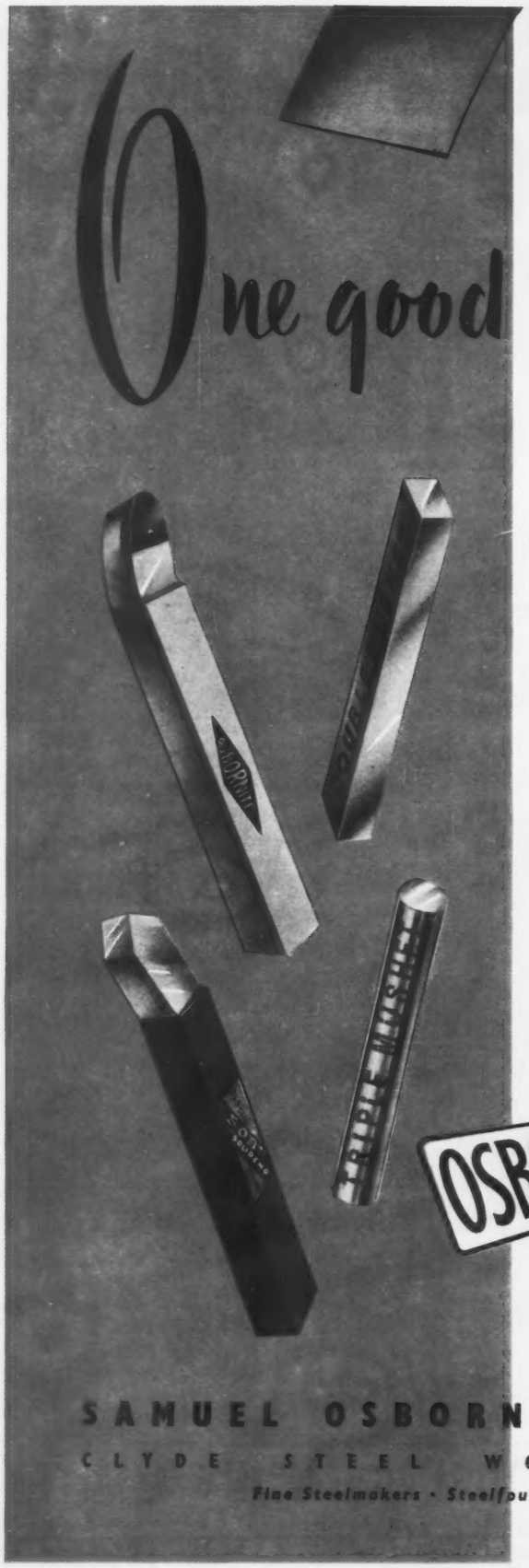

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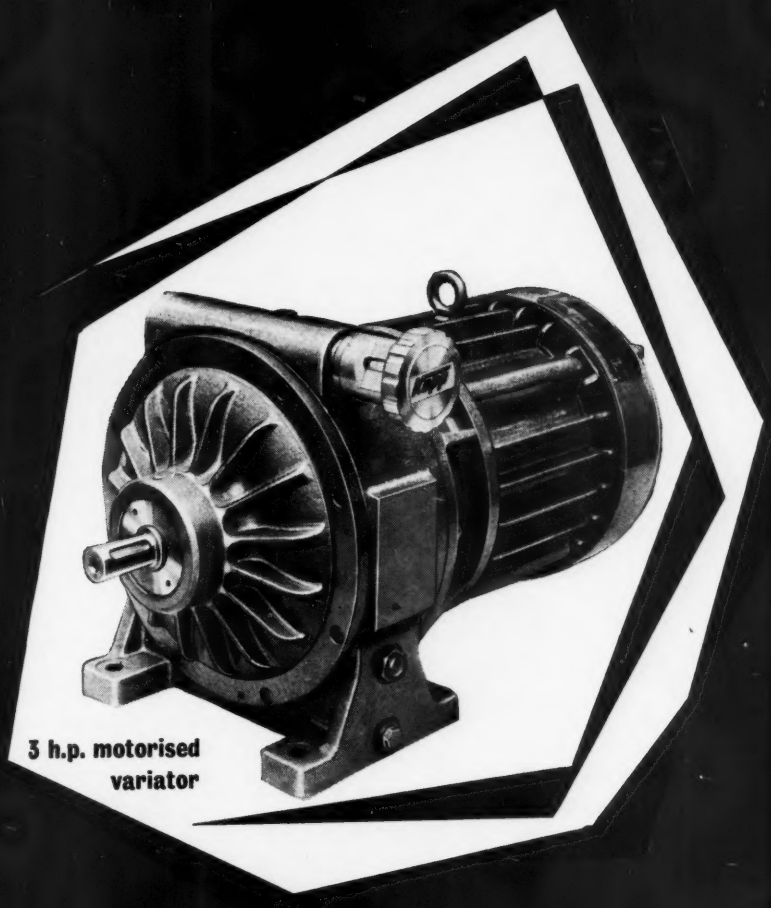

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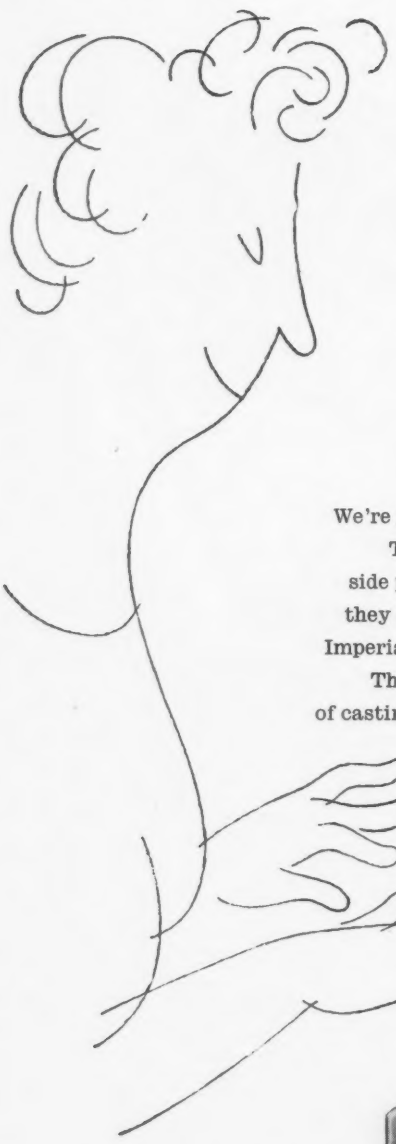

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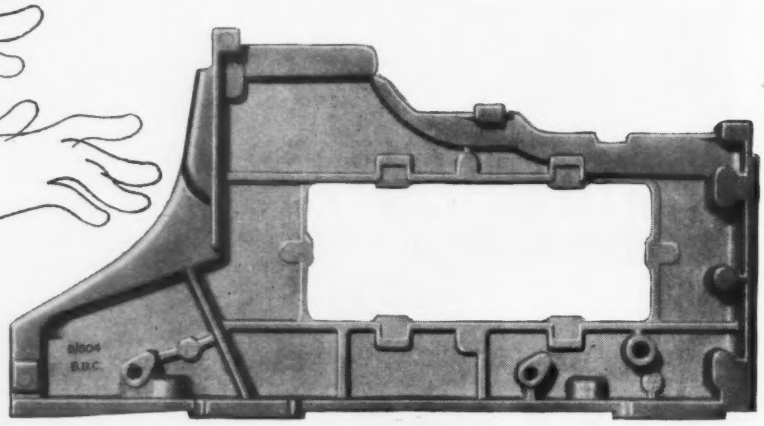

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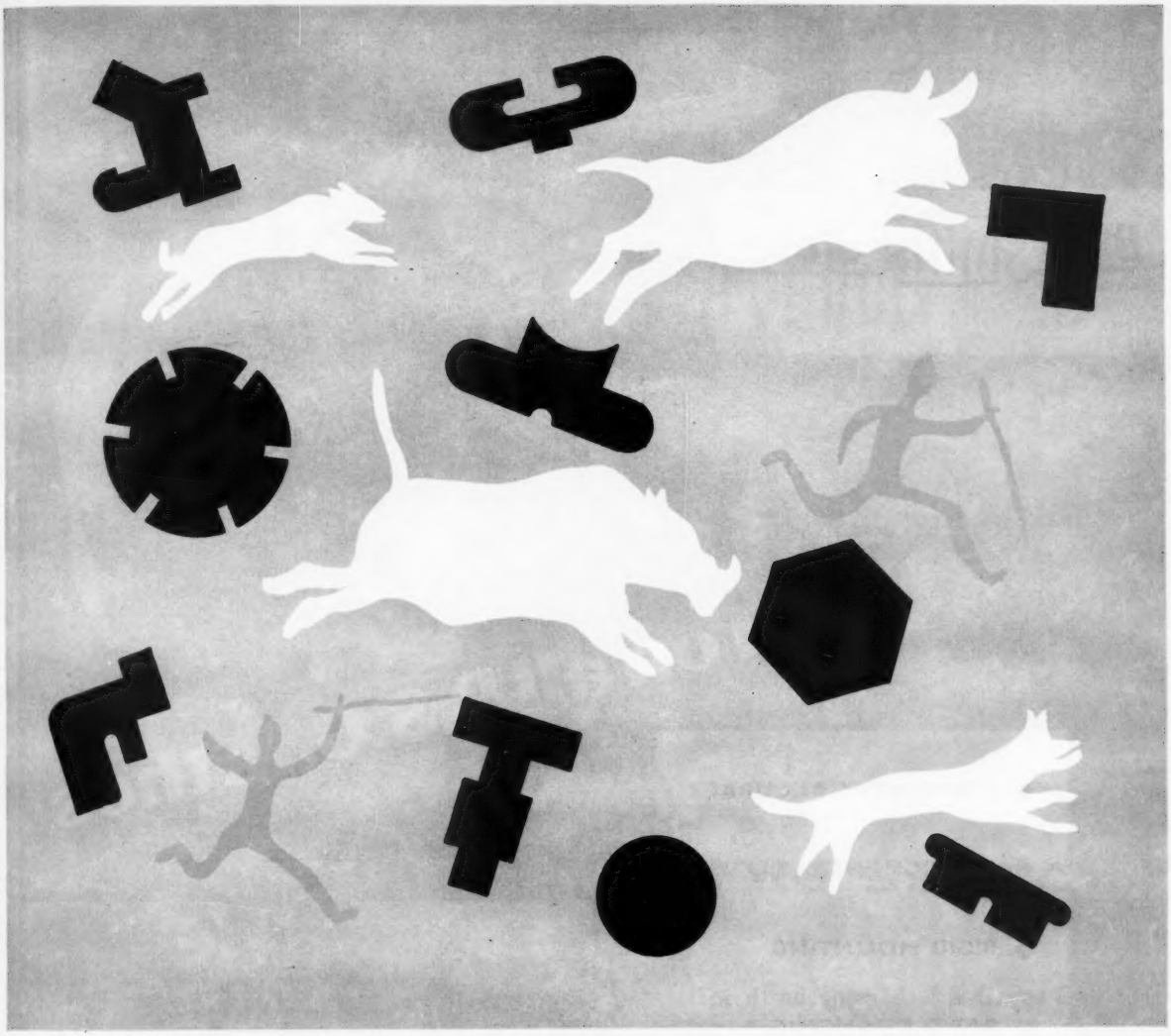

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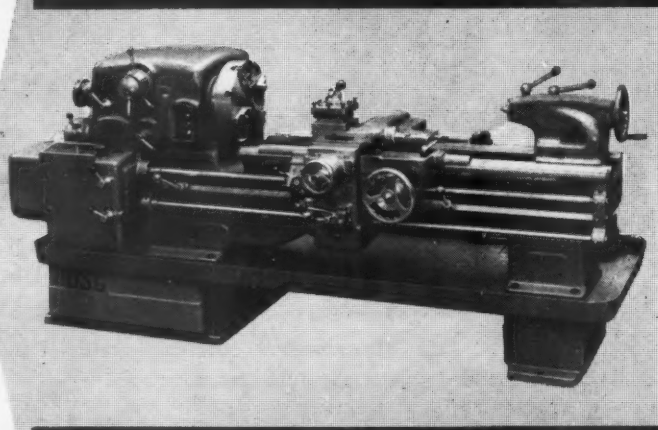

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Note the spindle bore size, and oversize Camlock flange on these types:

13" swing	D1-6"	1⅝" hole
17" swing	D1-8"	2⅝" hole
21" swing	D1-11"	3⅝" hole
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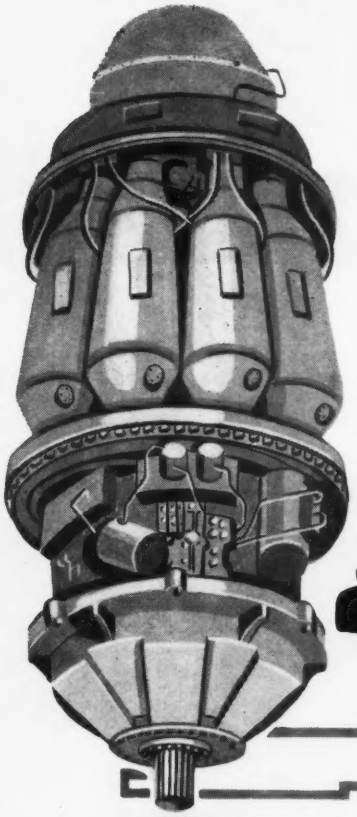

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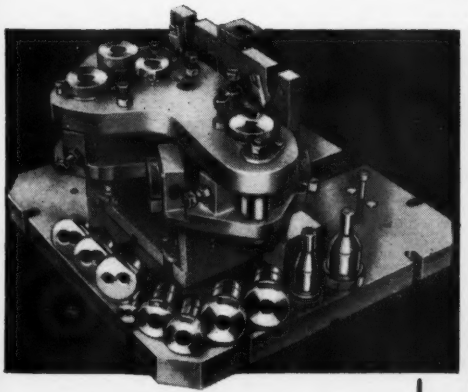

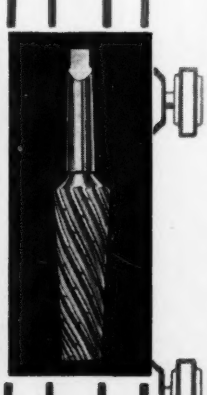

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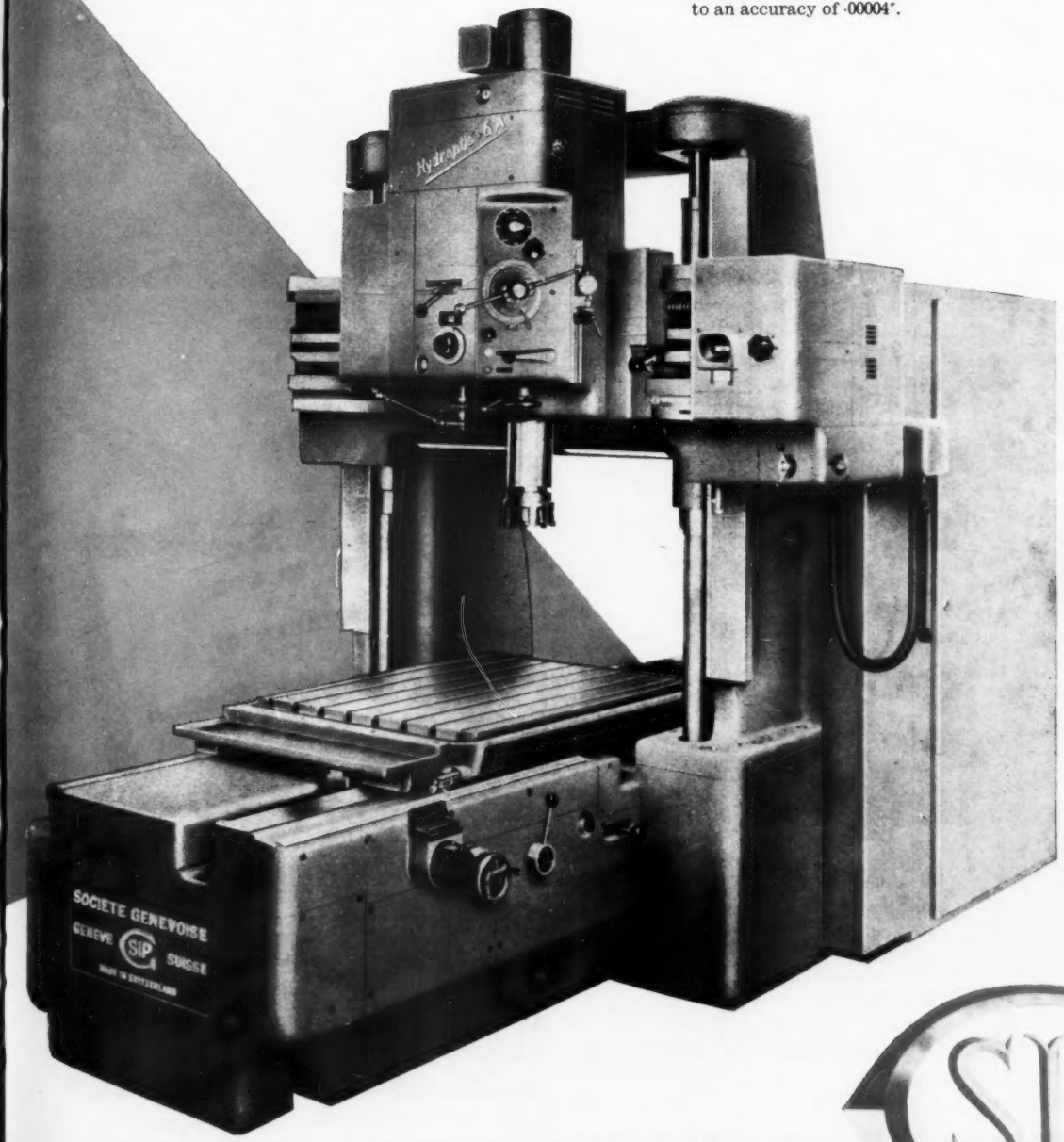

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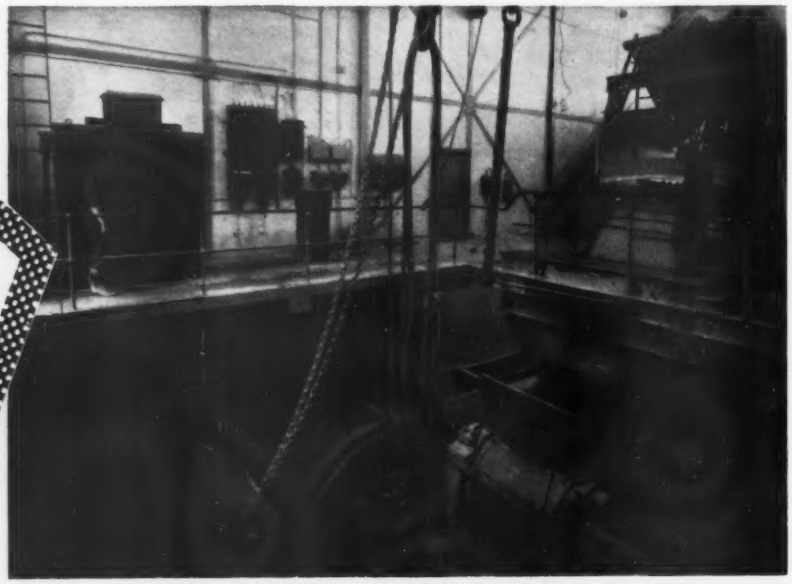
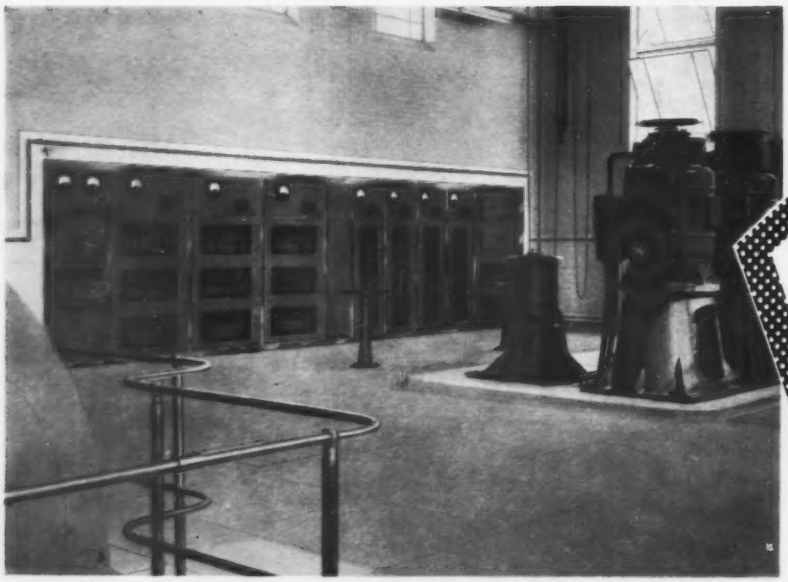


Contactor equipment providing hand-operated speed control of the Primary Crusher of Cornelly Quarry of The Steel Company of Wales Ltd



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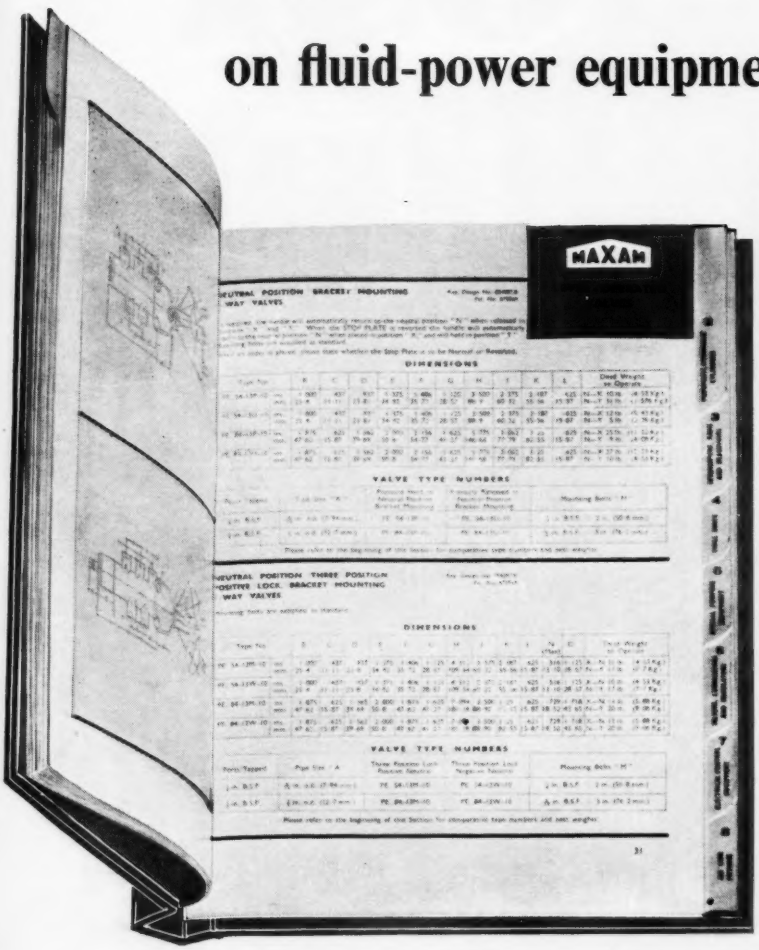

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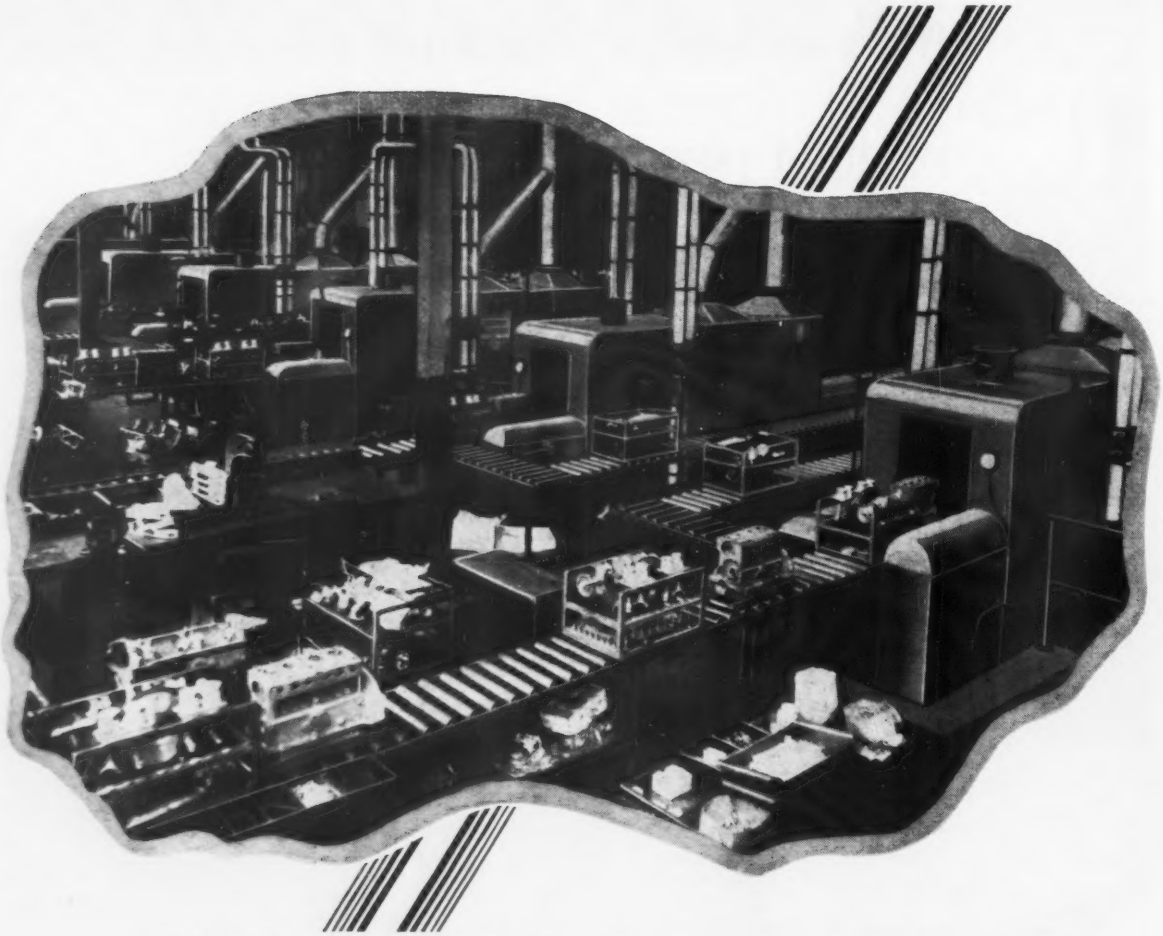

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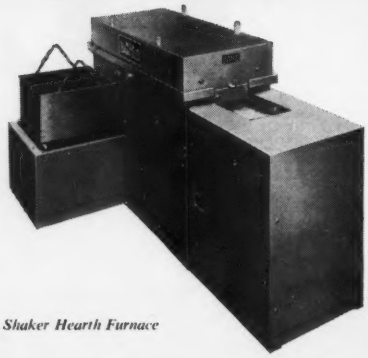

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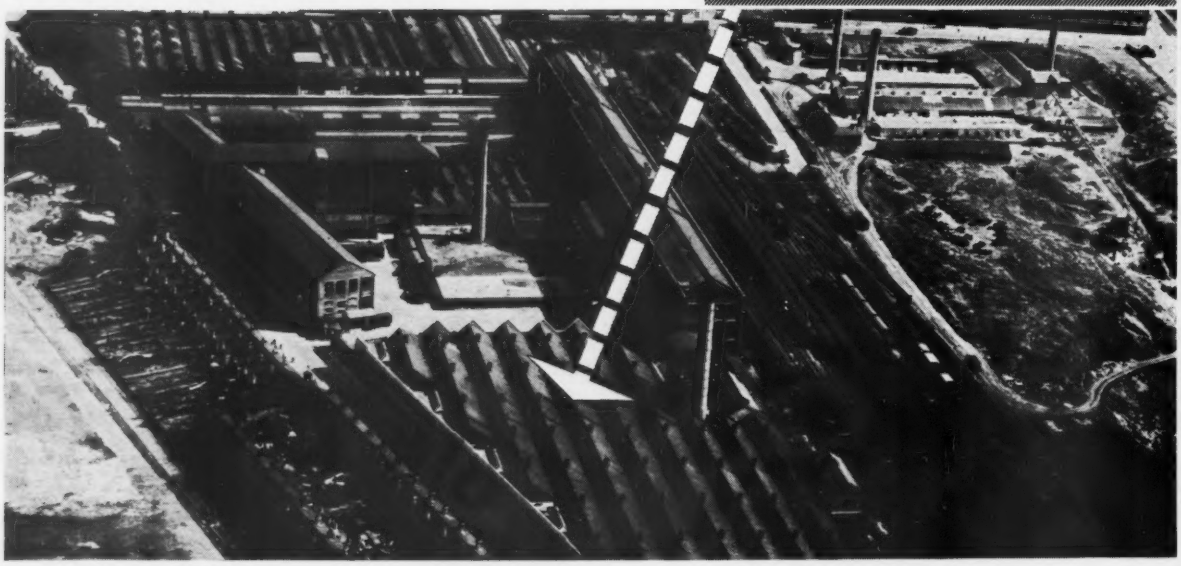

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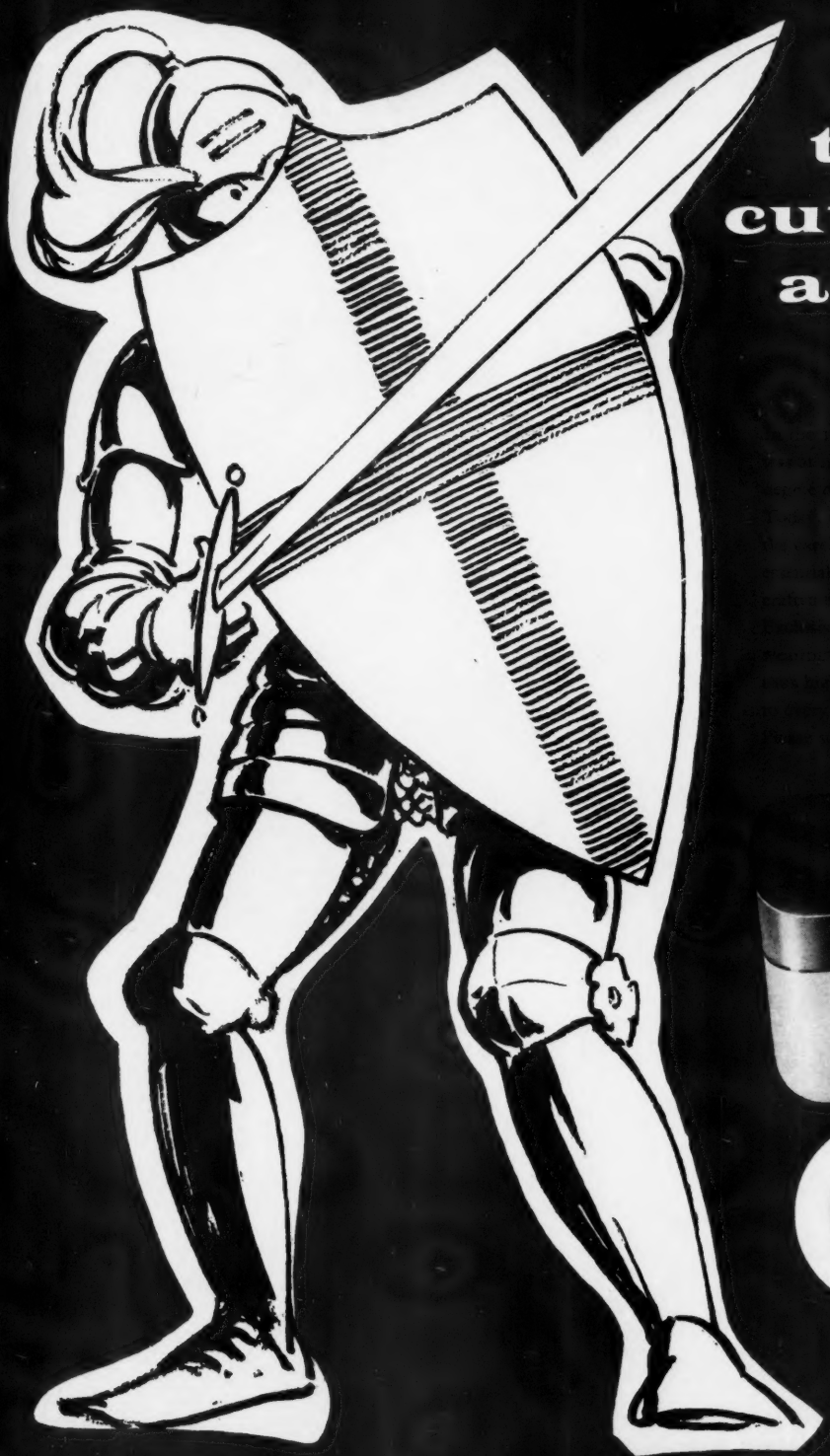

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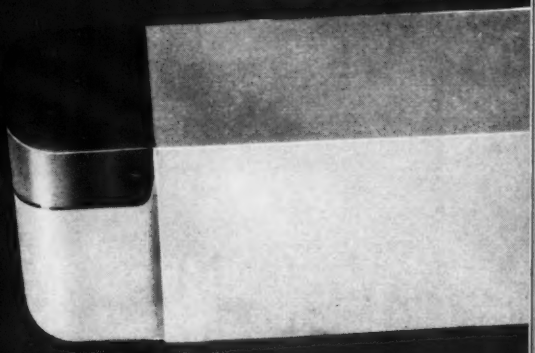

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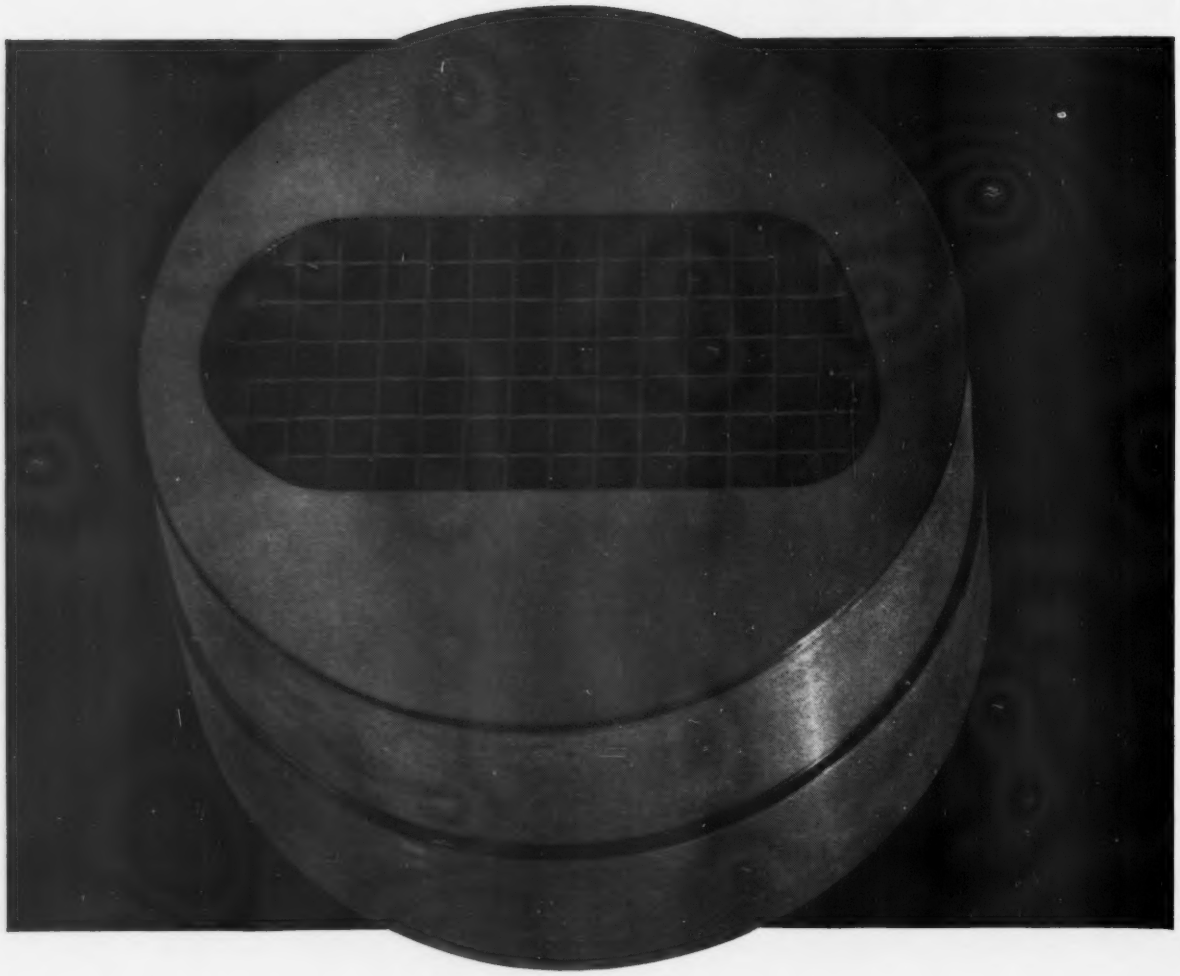

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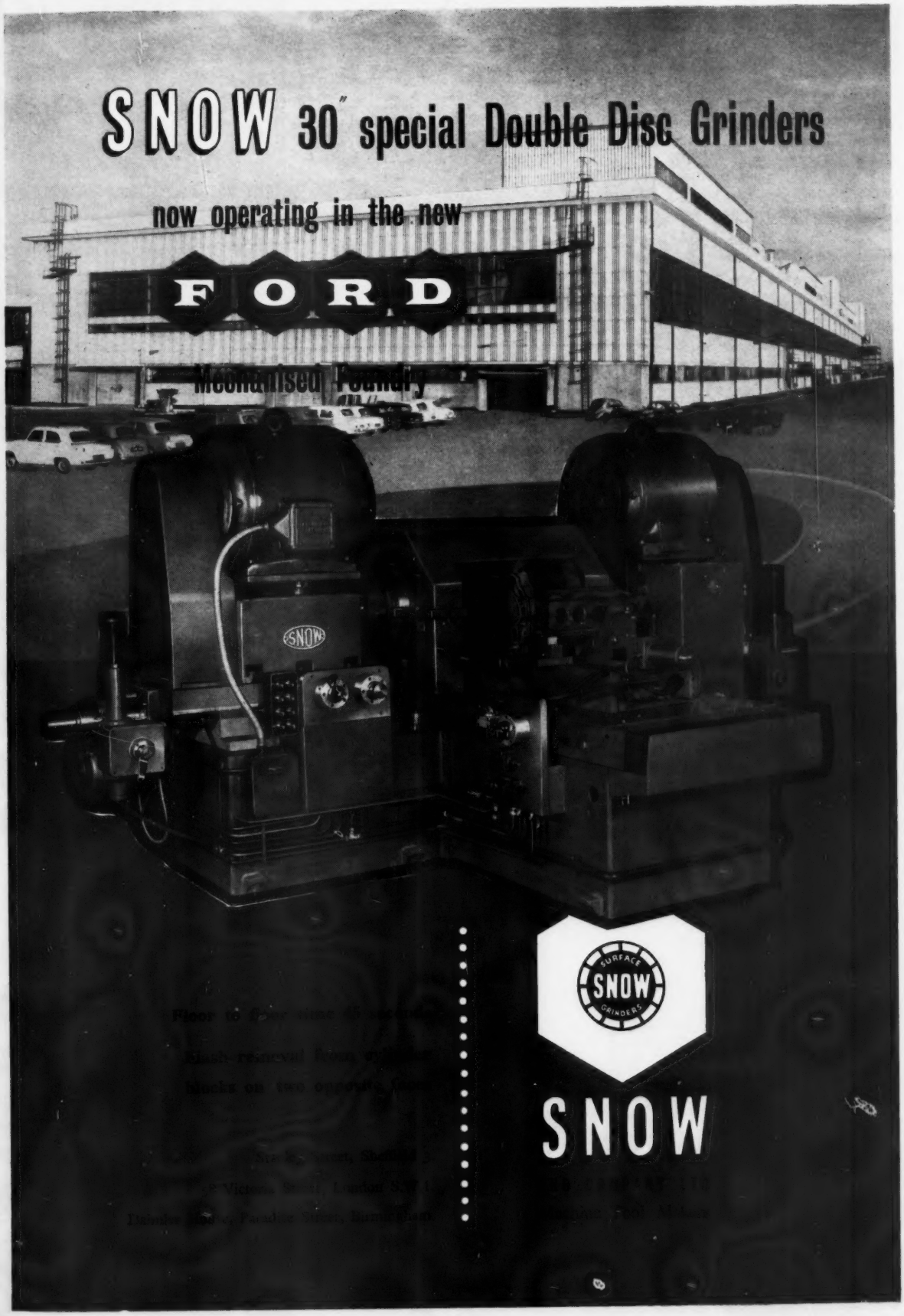
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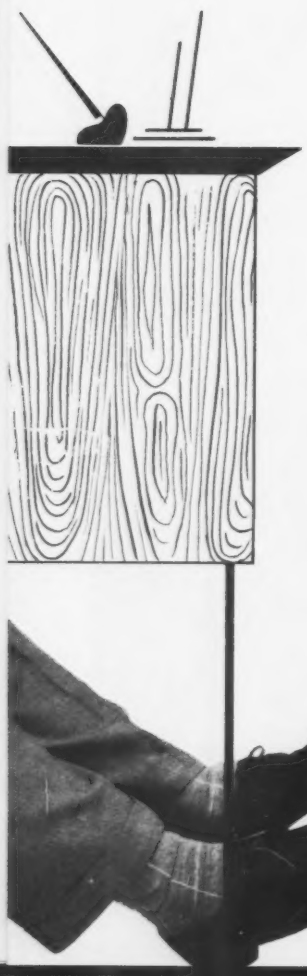

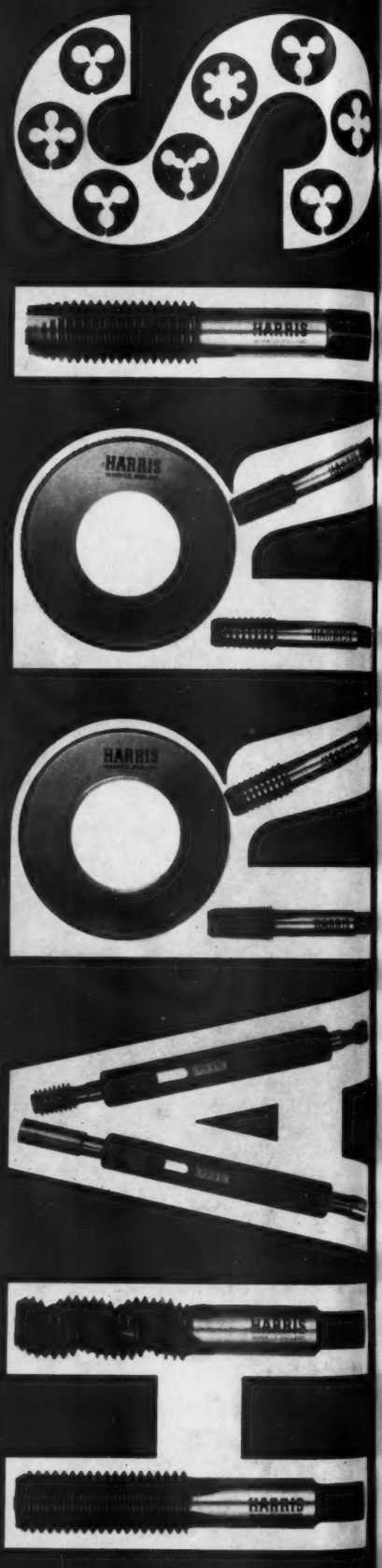

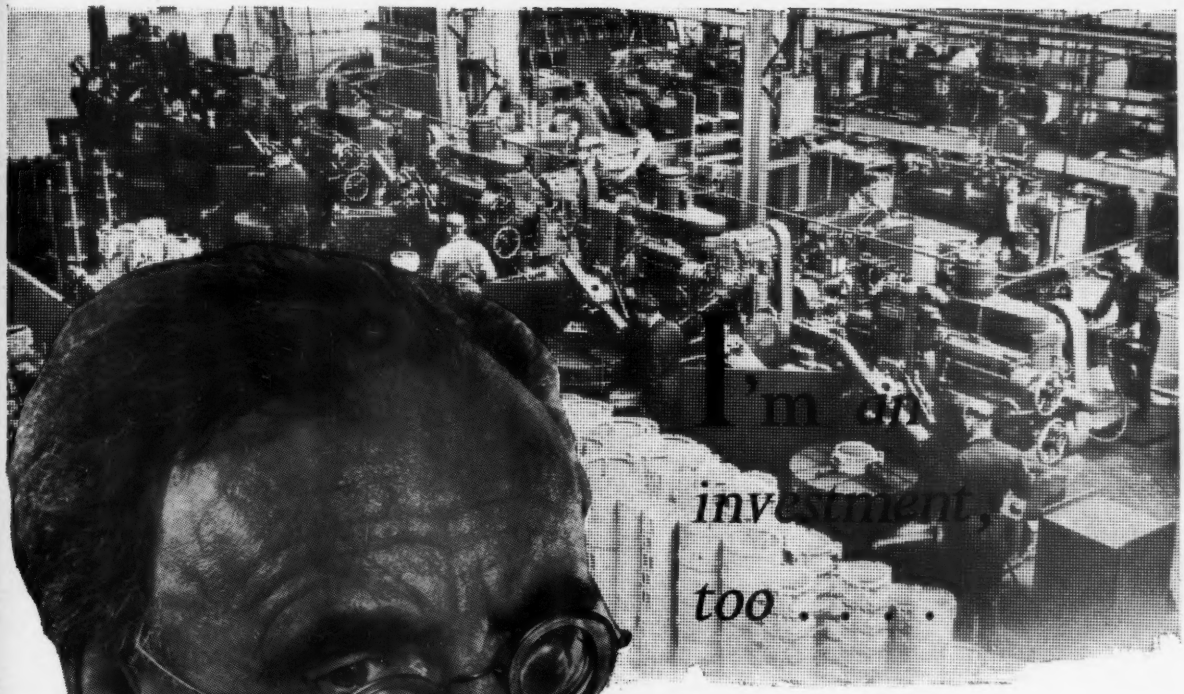

Someone once said;

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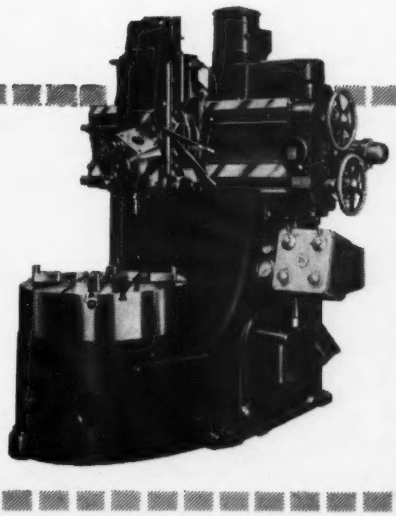
use it or lose it!"

That goes for us piece-workers too. Give us the chance to earn more by producing more, and we pay dividends.



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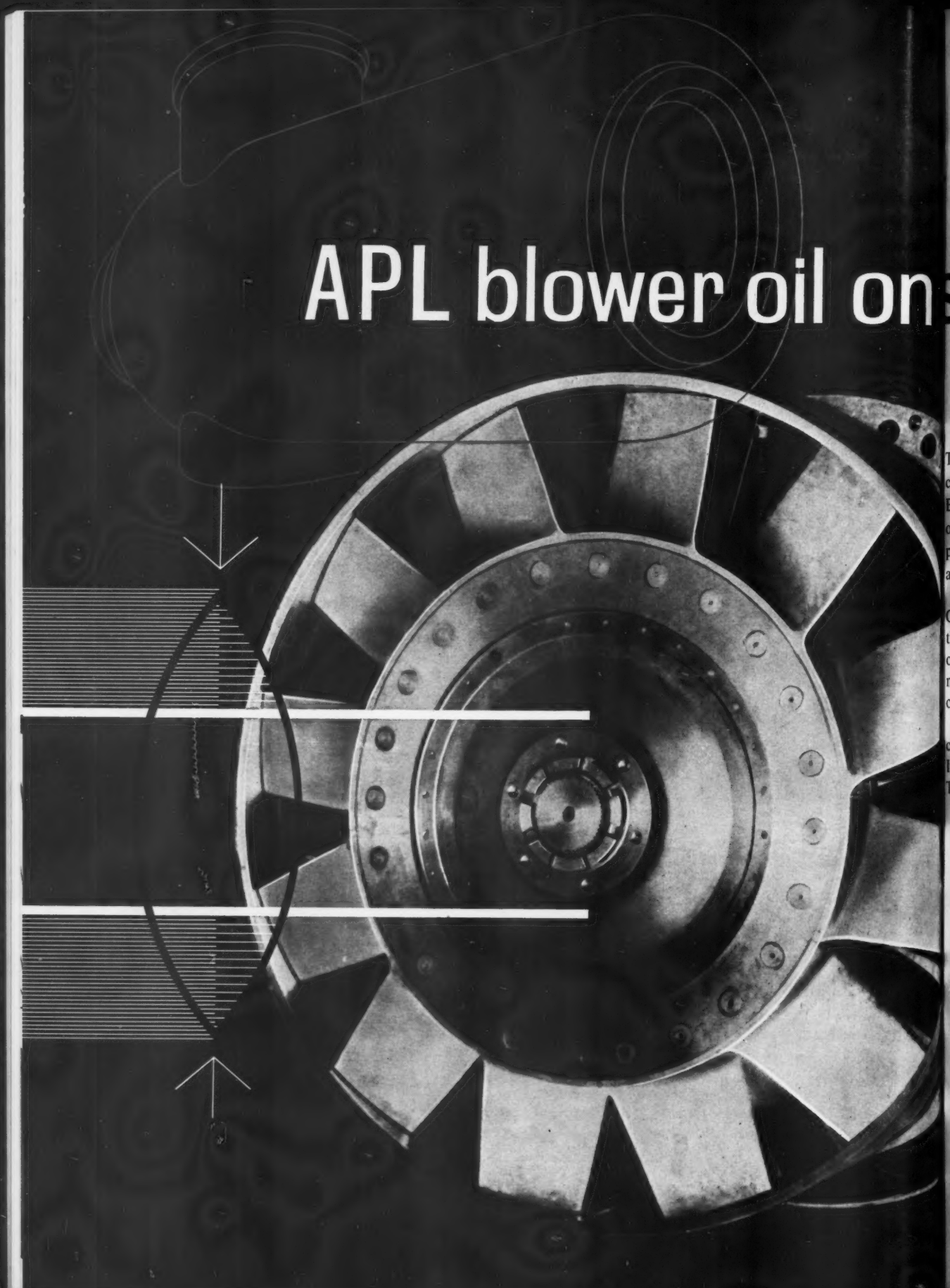


onsentry-go at Bradwell...

The crucial points of the high pressure CO_2 coolant circuit at Bradwell will be the blower shaft seals. Every minute of every working day Shell APL blower oil will guard these escape points—being continually pumped into the seals and bearings, led away, purified and recirculated.

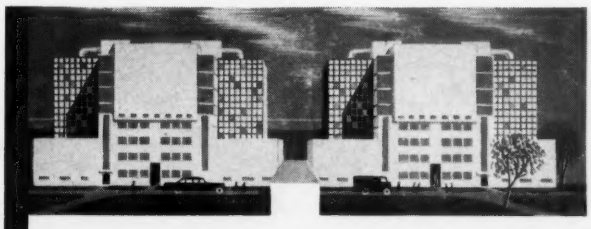
This very remarkable oil presents a two-way seal. Outwards, there is a minimum CO_2 loss as the oil has the lowest possible gas solubility. Inwards, in spite of the heat of the gas, oil vapour contamination is negligible thanks to the extremely low vapour pressure of the oil.

The research that went into APL blower oil is characteristic of the way Shell set about doing things. It was conducted at Shell's Research Centre at Thornton in close collaboration with the U.K. A.E.A. and the blower manufacturers. In the course of much fundamental research, a wide range of oils was subjected to vapour pressure and gas solubility tests in the laboratory. Selected oils from this range were used in the bearings and seals of a blower rig. In 1956, after four years of research, the finished product joined the Shell Atomic Power Lubricants range—marketed under the name of Shell APL 729. This oil has been in use at Calder Hall since the autumn of 1956.

The moral of the story is that Shell research is supremely applicational. The Centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubrication problem it pays to get in touch with your local distributor of Shell Industrial Lubricants.

The Research Story

Though the sealing action demanded of Shell blower oil is common in other industrial equipment such as hydrogen-cooled alternators, there were quite a few additional problems. It was necessary for the oil to have long life, low vapour pressure, low gas solubility, good thermal stability and high film strength —to be able to withstand high temperatures and to be resistant to all kinds of corrosive influences, including carbonic acid. The crux of the research was to combine all the above requirements into one oil, in order to minimise back diffusion of molecules which would contaminate the reactor.



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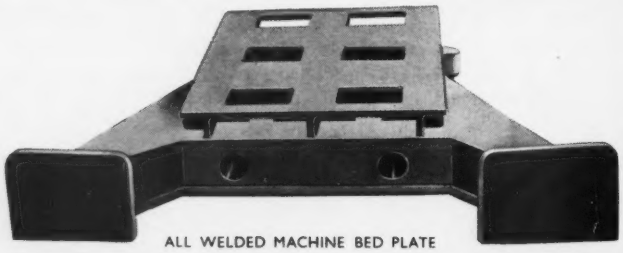

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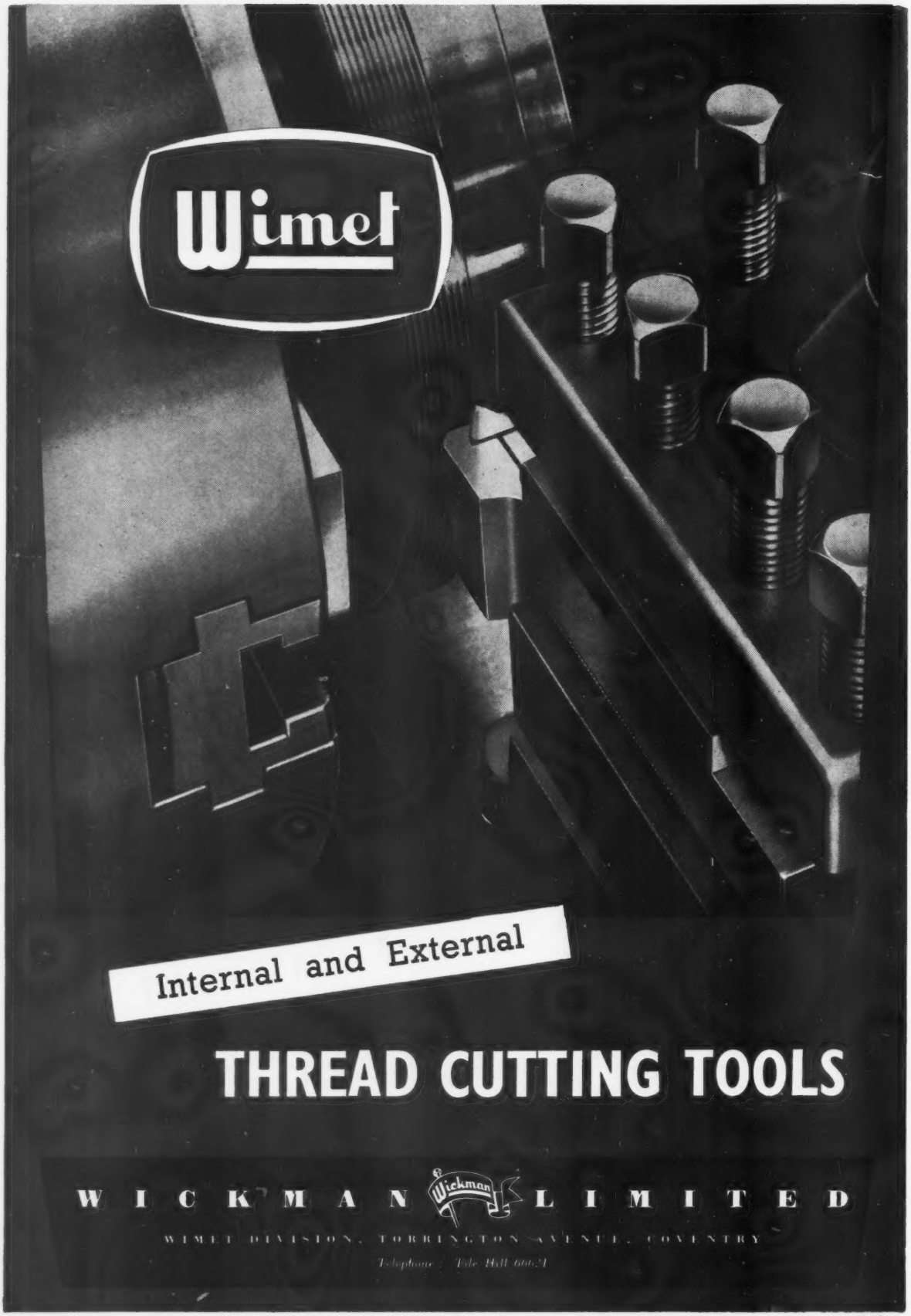
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The Institution of Production Engineers Journal
VOL. 37 No. 12 DECEMBER, 1958

The Annual Dinner

The Annual Dinner of the Institution was held at the Dorchester Hotel, London, on Wednesday, 29th October, 1958, and was attended by over 500 members and guests. The President of the Institution, The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P., M.I.Prod.E., was in the Chair, and the principal guest was Sir William Black, Chairman of the National Research Development Corporation.

During the evening the annual awards of the Institution were announced by the President and presentations were made by Sir William Black.

The President, in proposing the toast of "The Guests", said :-

THE year recently ended has been characterised more by a great deal of honest spade-work rather than by anything spectacular or revolutionary. The most important long-term event in the course of the Institution's year has been the finalising of our new examination scheme which will come into operation in 1960. This will, as it were, set the coping stone of the academic edifice which we have been building for so long.

Another solid job of work we have completed is the report of the Research Committee on Quality in Industry. I am glad to say that this Report was published in July of this year, and was favourably received by the national and technical Press.

In addition to the jobs which have been completed we have started some new ones. One, which I am sure will be very popular among Sectional and Regional Committees, is an inquest on the organisation and methods of our own Regional and Headquarters organisation! We have always felt it incumbent upon ourselves to practise what we preach, lest the old cry of "Physician, heal thyself" should taunt Headquarters! We have not had such an inquest for about eight years, since in fact we instituted what has now become known as the Burke Committee. We feel it is high time to check up on the general health of the patient and make sure that all is well.

raising the level of the best

For my part, I have had a busy and very instructive year on the affairs of the Institution. As usual this has taken me round the country quite a lot, visiting Sections and Regions and, of course, on each occasion lavish entertainment has been provided by my hosts. I should like to take this opportunity of thanking them for all the trouble they have taken in organising those visits, because invariably arrangements have been made for me to see the best examples of production engineering in any district that I have visited. This, together with my ordinary job at the National Research Development Corporation, has given me a wonderful ringside seat from which to see production engineering techniques. I cannot help thinking what a wonderful collection of industries and factories we should have in this country if the standard of the average was up to the standard of the best. In fact, that might almost be regarded as Britain's problem in a nutshell — raising the average to the level of the best.

The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P., M.I.Prod.E., President of the Institution (left), greets the principal guest, Sir William Black, Chairman of The National Research Development Corporation.

That, of course, is not a production engineering problem. It is a sociological and economic problem. We can but display techniques, and if people will not use them there is nothing a production engineer can do. I expect many of you, like myself, read a feature article in the *Daily Telegraph* this morning about the demarcation problem in the shipbuilding industry. It would have made one laugh if it had not made one want to weep. But there is nothing that we as production engineers can do about that. It is a social situation and not a production engineering situation. Our problems are not those of raising the standard of the average to that of the best, but of raising the level of the best. That is where production engineering research must be directed.

In this connection two problems have struck me rather forcibly in the course of my various visits to factories during the last two years. Each seems to be a challenge of some kind to the production engineer.

The first is the transformation in production techniques which occurs between production to sub-assembly stage and production to the finished product stage in certain classes of manufacture. The automobile industry has solved this problem. Optional extras, such as power steering, or automatic gear change, together with alternative colour schemes, give the customer a very real selection and do not interfere with flow production in such a way as to raise costs. But there are other classes of manufacture where this problem has not been solved. They affect industries making, for example, automatic telephone exchanges, typewriters, invoicing equipment, and the whole range of punched card handling equipment. In these cases the customer wants more selective specification than the manufacturers can give, except at the very heavy price of interfering with flow assembly methods.

In the production of a large invoicing machine, variation of type must represent the same production problem as varying the colours of motor-cars on the assembly line. But you cannot so easily incorporate an extra adding register. Its provision means drastic modification of the chassis, and transforms the character of production.

Extending the methods which have been used in the automobile industry to cover other products seems to be an outstanding challenge to production engineers. It is a challenge which has not yet been met by any kind of answer. I do not suppose that the answer will be found only on the machine shop floor. It must be an answer found jointly by the concerted efforts of the designer, the economist and the production engineer.

The other problem which has forced itself on my attention during the course of the year is the relative slowness with which industry is reacting to new methods of electro-mechanical metrology which are coming into being as a result of pioneering work in the optical division of the National Physical Laboratory. I believe that the seeds of a great revolution in engineering metrology have been sown. Engineering metrology was one of the issues on which the founders of this Institution decided to go out into the wilderness to face the hazards of founding a new profession. Advances in engineering metrology, therefore, are not matters to which any production engineer can be indifferent. These new techniques give us the possibility for the first time of manufacturing really perfect gears and really perfect screws by mass production methods.

signs of the times

It seems to me to be a slightly sinister sign of the times that when the Ministry of Supply sought contractors with whom to commission the construction of a machine using these new methods, their selection fell upon a firm outside the machine tool industry. I would feel much happier if it had fallen to a firm inside the industry. There is another slightly sinister indication that all is not well. When one of our leading electronic and control engineering firms sought a machine tool firm with which to associate for the purpose of producing electronically-controlled machine tools, their selection fell upon the subsidiary of an American concern rather than a British concern. I recommend those two signs of the times for very serious consideration.

It is often said that we are original in invention but slow in development and execution. My own experience is that the fault for this lies as much at the door of the consumer as at the door of the producer, because the pioneer producer is helpless without support from the pioneer consumer. The latter is the man who will buy, use and try out a new product to see how it works. He will not ask his accountant to prove to him forthwith that it will show a profit. No one will make pioneer goods for stock. If consumers will not place orders for new products then there is nothing that the pioneer producer can do about it. In this connection, it seems to be important not to ask too many questions prematurely about what a piece of revolutionary equipment will do. I have had the privilege of a ringside seat at the councils of those who are engaged in developing the new and very fast electrical calculating machines known as computers and this has given me many opportunities to study right and wrong attitudes to them. I can remember an occasion when I went up to one of the main producing centres of a big group, accompanied by my host who was a member of the main board of the group. In my presence he asked the general manager of the regional producing centre what had been done about a six months' old directive to acquire a computer. "Well", replied the regional manager, "we have here a list of computers whose performance we are studying, but it is very difficult to make a precise assessment as to the different merits of one machine and another." My host then pointed to the first name on the list and said: "Is there anything wrong with that one?". "No", said the regional manager, "there is nothing actually wrong, but . . .". "But me no buts", retorted my host, "you are to order that one on Monday unless you can think of something better in the interim. I want to find out what it will do." That is the only possible attitude towards revolutionary equipment. I hope you will forgive me for using this opportunity to talk of these matters, but they seem to be of importance.

I will now return to my business which is to propose the health of our Guest of Honour, Sir William Black. Sir William is my Chairman at the National Research Development Corporation, a post which he was offered and accepted some 15 months ago. It did not take us more than the length of one board meeting to become friends. We have been told for a long time past that British technical education must be terrible because the Russian variety is so marvellous. The only discordant note in an otherwise unanimous consensus of opinion seems to have come from Mr. K, who has recently announced that much of Russian education is phoney. Large numbers of students have accordingly been sent off to factories to learn what practical engineering means. May be our system of education is not quite so bad as its critics allege. Perhaps a system which has carried Sir William from an apprenticeship in Barrow to the Managing Directorship of A.C.V. and the Chairmanship of A.C.V. Sales has something to recommend it after all.

In addition to his positions in the field of manufacture he has won distinction for public work in many fields: in the S.M.M. & T., for example where he has held most of the offices up to and including that of President; in the Motor Industries Research Association of whose Council he was a founder member; as a director of Suez Contractors Limited, which carried so heavy a burden of responsibility in recent years; and finally as Chairman of the National Research Development Corporation to which he was appointed in that — for me — happy hour when our paths first crossed.

I give you the toast of our guests, coupled with the name of our Guest of Honour, Sir William Black.

Sir William Black, in response, said:

MAY I first discharge my official duties and thank you on behalf of all your guests for the warmth of your welcome and your great generosity this evening. Especially may I thank you, Mr. President, for the very kindly and flattering things you said about me. I may remind you of those some time in the future!

You have referred to our work in the National Research Development Corporation — an association which I have enjoyed very much. I feel that we labour together in that connection on a worthwhile task.

The Rt. Hon. The Lord Hives, C.H., M.B.E., receives from Sir William Black an Award for The Viscount Nuffield Paper, 1957.

development of ideas

I should like to take advantage of this opportunity with so many prominent industrialists present to touch very briefly on one aspect of the work of the Corporation which I do not think is widely appreciated. We have funds available which we can allocate in the form of risk capital in helping to develop and to exploit ideas and inventions which might otherwise lie dormant. I am not only referring to the lunatic fringe!

I believe that had the Corporation been in existence between the Wars, and had we taken up Whittle's jet engine which was well within our compass, we might have won the War a year sooner. We are, of course, using Government money, and our remit in the long run is to be self-supporting. Therefore, if we go into partnership with an inventor, we do so on a business footing. If the invention is a flop, we lose our money. On the other hand, if it succeeds, we want our pound of flesh.

As I look round this gathering, and a sea of friendly faces, I am reminded of the day when I left my north country home town to seek fame and fortune in London, where I thought there would be less competition! An old friend saw me off, and he happened to be a coal merchant. As he bade me goodbye, he said: "Try and make friends of people you meet in business". "But", he continued, "if you do business with friends, be very careful." Then he added: "You have always bought your coal from me and because you were a friend of mine I always knocked 5% off your bill, but because I was a friend of yours I only delivered 19 cwt. instead of a ton"! I am quite sure there is a moral in that somewhere.

setting the pace

We in the Research Development Corporation have other points of contact with you, both direct and through the Research Association. Today we live in an exciting and challenging age. The engineer is very definitely setting the pace of civilisation. Whether the ultimate result will benefit mankind remains to be seen. It may yet send us to destruction. If we remember that for thousands of years the highest speed which man could attain was governed by that of the horse, and when we reflect that in the short period of approximately a generation the fantastic speeds which are now being attained are being looked upon as commonplace, I find it frightening. Very soon one will be able to see a friend off at London Airport just after midnight, and will hear that friend say: "I will ring you when we get to New York yesterday"!

In all spheres technical progress gathers momentum. I have referred to transport, because that is a branch of engineering with which I am most directly connected; but advancement in other spheres is equally great. I recently visited Harwell and met some of the new scientists who amazed me by the way they accept as commonplace staggering new basic conceptions. One of them when discussing a certain plant said: "It is not very efficient. We get only a small proportion of the energy we put in, but we have only 5,000,000° temperature in the core. Once we get 100,000,000° this will be easy"! To me there is no difference between 5,000,000° and 100,000,000° of heat. I feel like the fitter when he was first introduced to the decimal system. He turned to his mate and said: "Bill, how many thousandths are there in an inch?" "Blimey", replied Bill, "millions"!

forging ahead

The Institution which you, Sir, adorn, is very definitely in the van of progress. Your members must and do keep looking ahead. One cannot imagine production engineering taking a backward facing seat in the train. That will be left to the accountants!

To get back to this question of engineering, there is no doubt that the international rat race is on and the devil take the hindmost! Our country with its sparse resources in primary products must get in the vanguard. Already international competition is fierce, and as the Iron Curtain lifts it will become much more fierce. We have no choice but to continue as an industrial and a trading nation. The old days when our forefathers were building up our greatness are gone forever. However attractive the age of elegance may have been when viewed in retrospect, and however desirable the advancement of fine arts may be, it is my contention that the best brains of the country should now be steered towards science and industry. I feel there is still a tendency at some of our best schools for promising students to be directed away from the practical subjects.

Your Institution does a great deal to stimulate the advancement of knowledge of production problems among the up-and-coming generation. I would venture to suggest that the high status now held by the production engineer is largely due to the work of the Council and members of your Institution. You also provide a wonderful opportunity for the interchange of ideas between specialists, and how we all love to talk shop!

importance of simplification

I think I have indicated clearly that I am an admirer of your work. Perhaps, therefore, I can venture to strike a mild note of criticism. Today the cost of tooling up any new project is a major factor in any industrialist's budget. It may even become prohibitive. In any type of manufacture it is tremendously valuable to maintain a degree of flexibility, so as more readily to take advantage of changing world conditions. If production costs continue to rise at their present rate, we are in danger of becoming bogged down and immobile. I suggest that some of your production genius should be channelled towards simplifying, hence cheapening, the remarkable plant and equipment which many of you create, otherwise you may drive some of us back to the pick and shovel mentality. Perhaps I should have said the knife and fork mentality which is a better simile this evening, because it is not an occasion upon which costs of production should raise their ugly heads!

Lord Halsbury receives from Mr. H. E. Honer, Hon.M.I.Prod.E., a bound volume of correspondence relating to the foundation of the Institution.

I hope I have not transgressed from your laudable desire to keep down the number of words per square meal! If the only purpose of your Institution was your Annual Dinner, I for one would say you have fully justified your existence!

On behalf of all your guests, thank you very much.

PRESENTATIONS

Sir William Black then presented the Institution's Awards and Medals, as follows :-

The George Bray Memorial Lecture, 1957
Dr. V. E. Yarsley
for his Paper entitled
"The Fabrication of Plastics"

The Sir Alfred Herbert Paper, 1957
Dr. H. Barrell
for his Paper entitled
"The Bases of Measurement" *

The Viscount Nuffield Paper, 1957
The Rt. Hon. The Lord Hives, C.H., M.B.E.
for his Paper entitled
"Technical Education for Production Engineers"

The Lord Sempill Paper, 1958
Boyd K. Bucey
for his Paper entitled
"Manufacturing in the Aeronautic Age" *

The E. W. Hancock Paper, 1958
Lewis T. Wright
for his Paper entitled
"Human Relations in Industry — Men, Women and Work"

Institution Medal
For the best Paper presented by a Member, 1956 - 1957
J. A. Grainger
for his Paper entitled
"New Techniques in Sheet Metal Forming"

Institution Medal
For the best Paper presented by a non-member, 1956 - 1957
A. G. Thompson
for his Paper entitled
"Measuring and Forecasting Cost Data in Highly Variable Production"

* *These Awards were made in absentia.*

Schofield Travel Scholarship, 1957
J. D. Parson

The Lord Austin Prize, 1957
J. F. Percival
for his Essay on
"Education for Technology and Management"

Following the presentation of the awards, the President accepted, on the Institution's behalf, a bound volume of correspondence relating to the foundation of the Institution. This presentation was made by **Mr. H. E. Honer,** *as Honorary Member and Founder of the Institution, who said* :

the foundation of the Institution

To you, Sir, as President of The Institution of Production Engineers I have the honour and privilege of presenting on behalf of the Institution this bound volume of correspondence.

This includes a copy of my original letter dated the 17th day of November, 1920 — almost 38 years ago. That letter was addressed to the Editor of Engineering Production, Manchester, in which I stated that reviewing the letters of his correspondents, they had with few exceptions proved the necessity for an Institution of Production Engineers.

I stated that to enable this to materialise, I was prepared, with the help of those interested, to call a meeting to be held at a convenient centre. After

further correspondence it was finally arranged for a meeting to be held on Saturday the 26th of February, 1921, at the Cannon Street Hotel. At that meeting, which was well attended, after full discussion it was resolved that the Institution be founded.

From then on, men of high intellectual attainments have brought influence to bear on its activities. Their knowledge and advice in the Council and various Committees have built the Institution until today its achievements in the field of production and automation are acknowledged throughout the engineering world.

In the colleges for further education here in the British Isles and the Dominions overseas, students are bending to the task of fitting themselves for membership of their appropriate grade within the Institution. How proud we all should be of the success which the Institution now enjoys!

Mr. President, I thank you for the opportunity afforded me of making this presentation, and I am sure that under your guidance, the deliberations of your Council and the various committees, and the full support that members throughout the world together with the Secretariat and Headquarters staff are proud to give, the Institution will go on from strength to strength and so live up to the motto which is so artistically emblazoned on its notepaper.

In accepting the volume from Mr. Honer, the **President** said:

I am sure it would be your wish that I, as your President, should take this opportunity of thanking our Honorary Member, Mr. Honer, for a number of things. First of all, I must thank him for the gift of this beautifully bound copy of the documents leading up to the foundation of the Institution in which he played a leading part. Secondly, I must thank him for his generosity and care throughout the years in safeguarding these documents, and for having them bound in this beautiful form and presenting them to us for custody in the archives of the Institution for as long as time may last.

I am sure that it would also be your wish that I should thank him on your behalf for having been the man who planted the acorn which grew into the oak. As I said in my Presidential Lecture last year, "Great oaks from little acorns grow", and it was those who founded the Institution at that meeting in the Cannon Street Hotel to whom we all owe so much. They, in their turn, owed everything to Mr. Honer for having set the ball rolling.

Thank you very much again, Mr. Honer, for all your initiative in the past and your generosity in the present.

Mr. H. W. Bowen, O.B.E., Chairman of the Institution's Council, said:

IT is my duty tonight to thank Sir William Black not only for his very interesting address but for the excellent way in which he presented the awards.

Sir William Black is, as you know, the Chairman of the National Research Development Corporation.

Mr. H. W. Bowen, O.B.E., Chairman of Council, making the closing address at the Dinner.

He has told you a great deal about it, but there is one thing I particularly admire him for. He is the only man I have met for a long time who has been able to use Government money on risk without having to do anything more than just use it! Whenever I want Government money I find it most difficult, even if there is no risk attached to it! I congratulate you, Sir William Black. I think that is an excellent job in itself.

I think you have not only raised the average to the best, as the President so ably put it, but you have raised the best to the infinite. That is the best way I can put it. May we thank you anyhow, regardless of my fun, for the excellent way in which you have presented these prizes and, secondly, may we thank you for gracing our Dinner with your presence this evening.

I shall not sit down without saying something about the presence here of our founder, Mr. H. E. Honer. I think it is the highlight of the evening. We have here the gentleman who really started this Institution. I am sure he never thought when he started it that it would become what it is today, but I think that we are all extremely proud to have him here. It is a wonderful thing in the height of achievement which production engineers have reached today to be able to have our founder sitting with us at dinner. Thank you, Mr. Honer, for coming. We are proud of you; we are proud that you are here. We are honoured to have you. (*Prolonged applause.*)

Mr. Honer, in response, expressed his thanks for the very kind words which had been said. It was gratifying to him that on such an occasion he found he had quite a large number of friends there assembled. There was one man present for whom he had the utmost regard, and that was Mr. J. D. Scaife. Mr. Honer was proud to see him again, and trusted that he would be spared for many years to come to support the Institution in the manner in which he had supported it in the past. (*Applause.*)

The proceedings then terminated.

design and performance of two

MILLING FORCE DYNAMOMETERS

a report by

F. Koenigsberger, D.Sc., M.I.Mech.E., M.I.Prod.E.,

K. D. Marwaha, M.Sc.Tech., Grad.I. Prod.E.,

and A. J. P. Sabberwal, M.Sc.Tech.

WITHIN the framework of a research programme in which cutting forces during milling operations are to be investigated a three-dimensional (Fig. 1) and a two-dimensional (Fig. 2) milling force dynamometer were built and tested.

On each dynamometer a platform[a] carries the workpiece[b] on to which the milling cutter [c] exerts the cutting force.

The design of the dynamometers is based on suggestions published by the Massachusetts Institute of Technology[1,2,3]. Use is made of the existence of strain nodes at certain sections of a loaded circular ring, which make it possible to separate strain measurements under vertical and horizontal loads.

If a vertical load V is applied to a circular ring (Fig. 3) the maximum strain occurs along the horizontal centre line, whereas points of zero strain are located at 39.6° from the vertical. If the ring is constrained from rolling and a horizontal force H is applied, the strain nodes for this load lie along the horizontal centre line, and the nodes for the vertical load are strained.

Hence, under the action of the vertical force V, if resistance wire strain gauges are located at the nodes mentioned above and shown in Fig. 3, gauges 1 and 3 measure tension and gauges 2 and 4 compression. When the horizontal force H is applied, gauges 5 and 7 measure tension, and gauges 6 and 8 compression. Two Wheatstone Bridge circuits with four

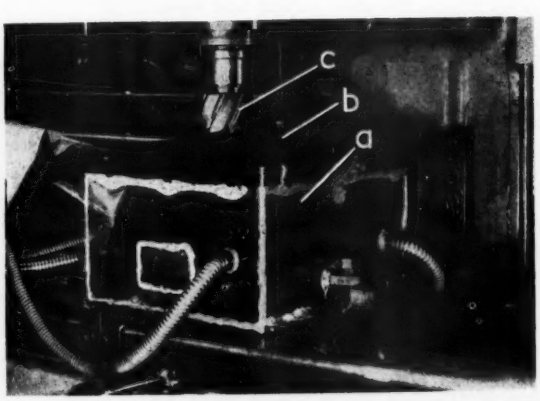


Fig. 1.

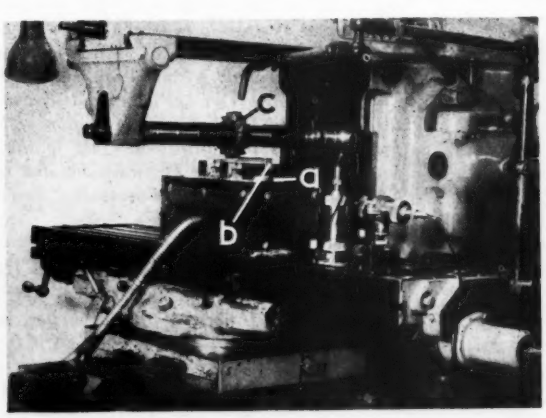


Fig. 2.

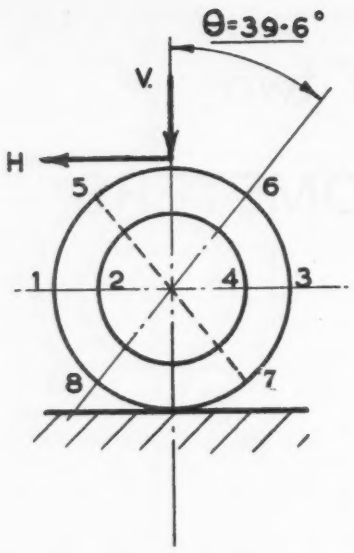


Fig. 3.

active arms in each can then measure two mutually perpendicular and simultaneously acting forces without mutual interference.

In practice it has been found more suitable to substitute circular rings by octagonal ones as these are easier to locate and to clamp, especially to prevent rolling. The strain gauges, which measure strains under a horizontal load, are applied to faces at 45° and not at 39.6° from the vertical, but this does not appear to affect the accuracy beyond permissible limits.

Three-Dimensional Dynamometer

In the three-dimensional dynamometer (Fig. 1) components of the cutting force are measured (Fig. 4) in a horizontal plane in two directions at right angles to each other (components H_A and H_B) and in a vertical direction (component V). Four octagonal rings, located as shown in Fig. 4, carry a top plate on which the workpiece is held. The rings are fixed to a base plate which is itself clamped to the milling machine table. The components of any force applied to the workpiece can be deduced from the supporting forces acting on the four rings. If the horizontal and vertical components acting on each ring are measured separately, not only the magnitude and direction of the resulting force but also its exact position in space can be calculated.

If only the magnitude and direction of the cutting force is required, the sum of the vertical components acting on the four rings as well as the sum of the horizontal components acting on rings 1 and 3 ($H_{A1} + H_{A3}$) and of the horizontal components measured by rings 2 and 4 ($H_{B2} + H_{B4}$) can be directly obtained on the measuring instrument by connecting the corresponding bridges in series.

Two-Dimensional Dynamometer

In many cases the measurement of only two components (Fig. 5) in a horizontal direction parallel to the feed movement (component H) and in a vertical direction (component V), may be required.

★ ★

the authors

Dr. Koenigsberger joined the Manchester College of Technology (now The Manchester College of Science and Technology) in 1947, and is now Reader in Machine Tools and Production Processes. He received his technical education at the Technical University, Berlin-Charlottenburg, where he graduated in 1931. After a period as Assistant to the late Dr. George Schlesinger, he worked as a senior draughtsman and designer in several machine tool firms on the Continent, his last job being that of chief engineer and chief designer of the Machine Tool Department of Ansaldo in Genoa, Italy. He came to the United Kingdom in 1938, and joined Cooke and Ferguson Ltd., of Manchester, subsequently becoming Chief Mechanical Engineer and Designer, mainly in connection with welded machinery structures.

Dr. Koenigsberger has served on Committees of the British Welding Research Association, the Institute of Welding, the Institution of Mechanical Engineers, and the British Standards Institution. He is a British delegate to the International Institute of Welding, and to the International Standards Organisation, and was a member of the British delegation at the Conference of Production Engineering Professors, organised in Delft by The Institution of Production Engineers in 1956.

Mr. Marwaha attended courses at the University of Delhi and the College of Technology, Bristol. After some years with Bristol Aircraft Ltd., he carried out research work at the Faculty of Technology, University of Manchester, where he obtained the degree of M.Sc.Tech. in 1958.

Mr. Sabberwal received the degrees of B.A. and B.Sc.(Eng.) in India. In 1956, he entered the Faculty of Technology in the University of Manchester, where he received the degree of M.Sc.Tech. in 1958.

In the simplified dynamometer (Figs. 2 and 5) two half octagonal rings support a rigid bridge piece on which the workpiece is clamped.

Constructional Material

The choice of material for the measuring spring elements (the rings for the three-dimensional dynamometer and the body of the two-dimensional dynamometer) lay between light alloys and steel. Light alloys have the advantage of low weight and better thermal conductivity. They are also easily machinable. Their main disadvantage is the instability of their physical strength properties, their stress-strain relationship not being truly linear and hysteresis effects, age-hardening, intercrystalline corrosion and creep being associated with many of them. As Young's modulus of steel is constant, mild steel was considered a safe and sound choice. It offers consistent physical strength properties over long periods, is not difficult to machine and corrosion prevention under laboratory conditions is manageable. Temperature compensation is allowed for in the electrical bridgework.

Design and Manufacture

Octagonal Rings

In the dynamometer shown in Fig. 4, a horizontal cutting force component also provides reactions on the rings in the vertical direction, the value of these

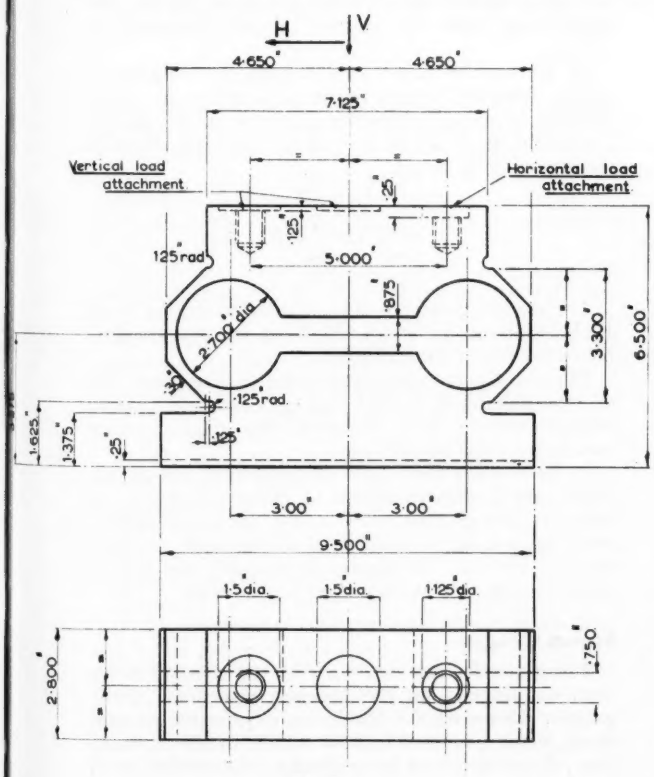


Fig. 5.

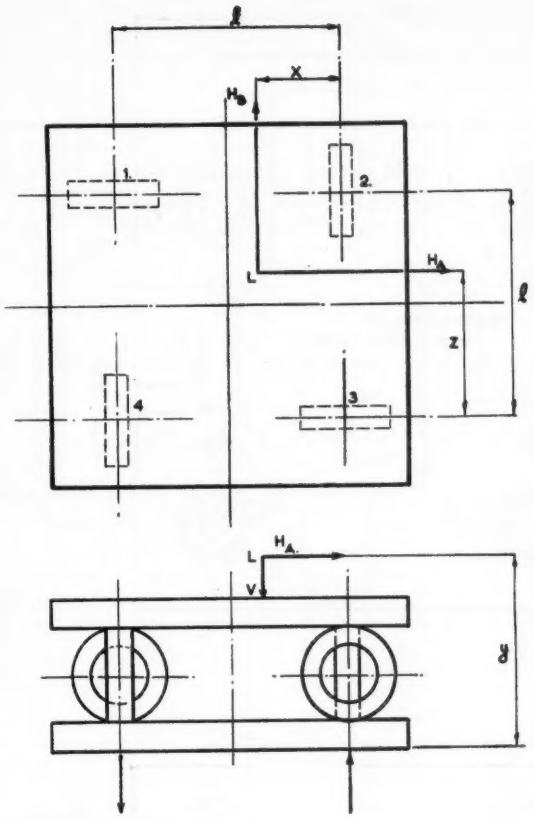


Fig. 4.

reactions being dependent upon the position of application of the force component and upon the geometry of the dynamometer.

The load capacity was therefore determined as follows:—

Maximum vertical component 'V' of the cutting force = 500 lb.

Maximum horizontal component H_A or H_B of the cutting force = 2,500 lb.

If the vertical component acts directly above one of the four rings, that ring would be subjected to a vertical force of 500 lb.

Horizontal component per ring due to either

$$H_A \text{ or } H_B = \frac{2{,}500}{4} = 625 \text{ lb.}$$

Maximum value of the total vertical reaction if both H_A and H_B act simultaneously along the axes of a ring = $(H_A + H_B)$ (Fig. 4)

$$= 5{,}000 \times \tfrac{5}{8} = 3{,}130 \text{ lb.}$$

(The spacing of the rings was first roughly estimated and the values of y and l assumed as 5 in. and 8 in. respectively.)

Total maximum vertical force which may act on a single ring = 3,130 + 500 = 3,630 lb.

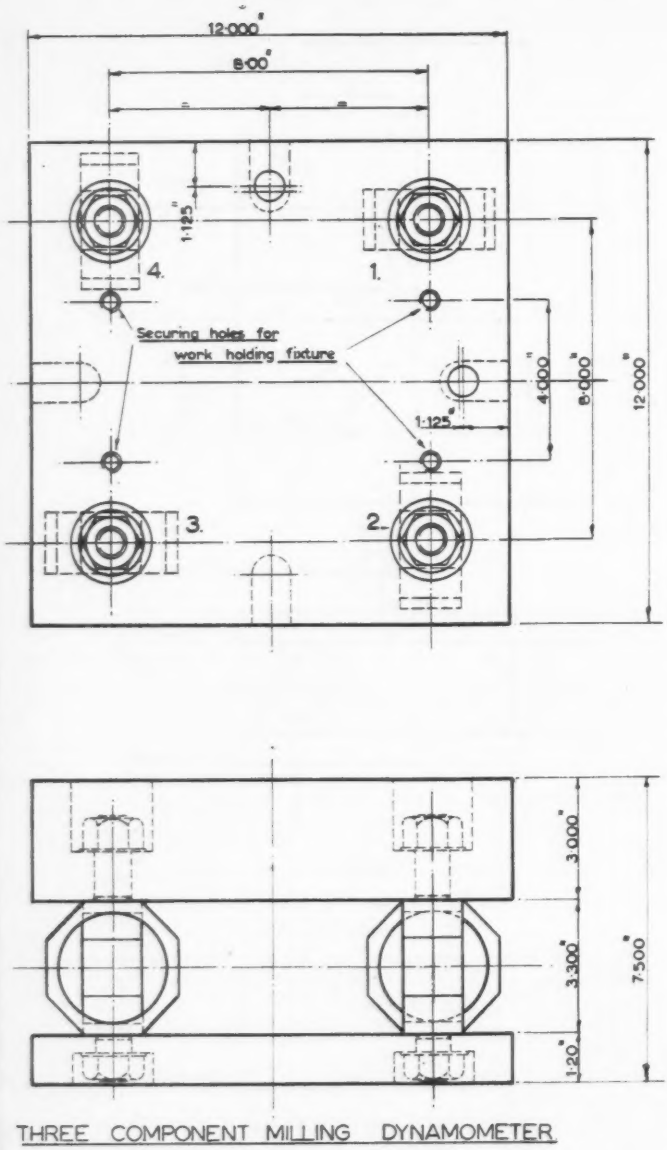


Fig. 6.

Strain at $\theta = 90°$ is given by

$$\varepsilon = \frac{0.7\,VR}{EWt^2} \qquad (1)$$

The mean radius was taken as 1.500 in. and the width estimated to be 1.500 in.

The maximum strain to which the strain gauges could be subjected, was taken as 0.001.

Then from Equation (1),

$$\frac{0.7 \times 3{,}630 \times 1.5}{30 \times 10^6 \times 1.5 \times t^2} = 0.001$$

or $t = 0.291$ in.

The wall thickness of the ring was chosen as 0.300 in.

Within the tolerances stated in Fig. 7:—

1. The four rings have to be identical in bore size.
2. The wall thickness across each face of the ring has to be uniform and all four rings must have identical wall thicknesses.
3. The spigot centre-lines must pass through the centre of the bores.
4. The spigot diameters must be identical.

The rings were produced from $1\frac{3}{4}$ in. thick mild steel plate material. After the rings had been flame cut to rough form, they were heat-treated at 780°C for one hour and quenched in oil, thus ensuring a uniform and fine grain structure in the metal.

Although the spigot diameters of the rings were identical to within .001 in., the holes in the top and bottom plates of the dynamometer were finished bored to suit each spigot in order to obtain the required interference fit between the spigots and their locating bores.

Two-Dimensional Dynamometer

When a straight-teeth cutter, i.e., a cutter with zero helix angle, is used and no face cutting occurs, the axial force component can be assumed to be negligible. For measuring the milling forces under such conditions the dynamometer is designed for a load capacity of 750 lb. in the horizontal and vertical directions. The thickness ' t ' of the ring portions and the mean radius were chosen the same as for the single ring, while the width ' b ' was increased to 2.8 in.

As far as the strain calculations are concerned similar formulae apply as for a single ring. The distance between centres has no effect on the strains caused by the loads as long as the bending effect of the top plate is small.

$$\varepsilon_{45^\circ} = \frac{1.4 \times 750 \times 1.5}{30 \times 10^6 \times 2.8 \times 0.09} = 2.08 \times 10^{-4}$$

and $\varepsilon_{centre} = 1.04 \times 10^{-4}$

The stresses corresponding to these strains for steel are 6,240 lb./sq. in. and 3,120 lb./sq. in., and are thus below the elastic limit of steel.

The two-dimensional dynamometer was made out of one single block of steel which, in order to remove residual stresses, was annealed after flame cutting and before final machining.

By machining the whole dynamometer out of one block, any unknown effects of clamping spigots or bolts are also eliminated. The top portion is sufficiently rigid to keep bending effects so small that the distance between the centres of the half rings has no effect on the strains measured under load.

Strain Gauges

Theoretically, the sensitivity of the dynamometer does not depend on the nominal resistance of the gauges. However, the maximum permissible current through the gauges is limited which, in effect, limits the voltage that can be applied to the bridge for a particular resistance. If the current is too high, the

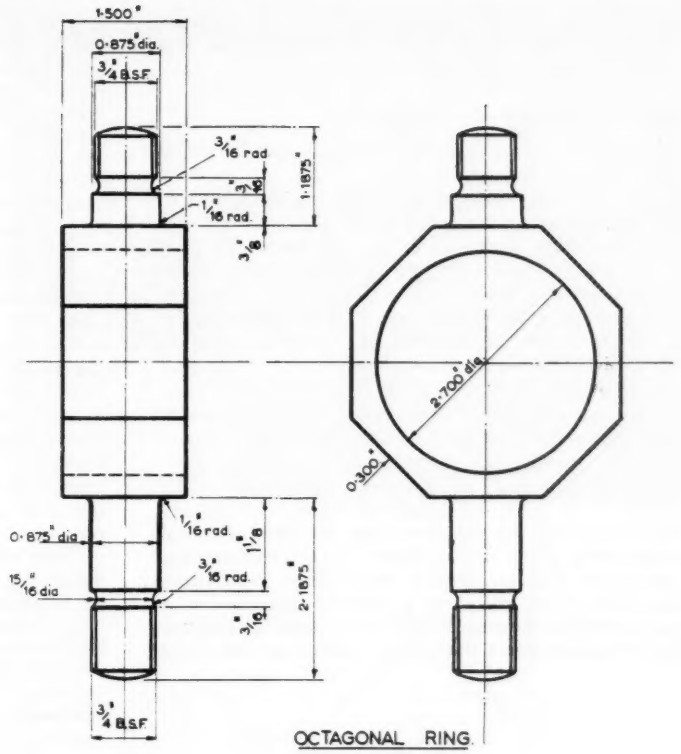


Fig. 7.

resistance wire will be over-heated and the adhesive will become soft and cause hysteresis and a reduction of the gauge factor. The maximum current does not differ for gauges of short length (low resistance) or long length (high resistance). The latter, however, are more sensitive since the bridge can be operated at higher voltages.

The choice of the resistance wire strain gauges was largely influenced by their grid size. Small grid sizes enable the gauges to be localized in the region of strain nodes thus minimizing mutual interference of the cutting force components.

The specification of the gauges is as follows:—

Nominal resistance R = 120 ohms $\pm$ 5% (tolerance per packet of 10).
Gauge factor G = approximately 2 $\pm$ 1.5%.
Grid type = flat.
Dimensions of paper carrier = 30 $\times$ 8.5 mm.
Dimensions of grid = 12 $\times$ 2.5 mm.
Maximum permissible temperature = 70°C.
Measuring current = 10 mA.
Maximum permissible current = 25 mA.

After the gauges had been applied and dried, they were covered with a layer of beeswax to provide against moisture penetration. The whole ring was then finally coated with a Tectyle rust preventive plastic moisture-proof film. Terminal discs were assembled to each ring. The assembly formed a complete unit from which strain gauge connections could be easily tapped.

Electrical Circuits

An important consideration in the use of resistance strain gauges under dynamic conditions is the choice between A.C. and D.C. bridge circuits. When very long cables are necessary to connect the strain gauges to the measuring apparatus, it is often preferable to use direct current. Cable capacitances do not affect the measured result as much with D.C. as they do with A.C.; the amount of current drawn from the batteries can be controlled more easily and heating of the gauges reduced. However, with D.C. care must be taken to avoid possible occurrence of thermo-electromotive forces and contact potentials. Moreover, a D.C. amplifier required for amplifying the bridge voltage is rather a complicated and costly apparatus; an A.C. amplifier, even when designed for greater stability, is simpler in construction. In the present work a D.C. bridge was used in view of its availability.

The amplifier must have a frequency response much higher than the frequency of load variation, and it must be free, as far as possible, from drift and noise. At the input stage the noise factor of the amplifier should be such that the signal to noise ratio should be as large as possible. In the case of both dynamometers the amplifiers were used at highest gain and the necessary attenuation obtained by means of the oscilloscopes. This was done because the amplifiers had the highest stability at the highest gain, and the

gain of the overall system could be checked by feeding a known voltage for which provision was available in the unit itself.

Three-Dimensional Dynamometer

The electrical circuit should satisfy the following requirements:—

1. Independent sensitivity control for each bridge;
2. independent balancing of each bridge;
3. indication of current in each bridge;
4. measurement of the output of each bridge alone or the summated output of all relevant bridges;
5. possibility of selecting any of the three components of the cutting force for recording purposes whilst cutting is in progress;
6. provision for an on-off current supply switch.

The necessity of having an independent sensitivity control over each bridge is obvious if its output has to be recorded separately. Apart from this, it is a desirable feature even if only the three components of the cutting force are to be measured directly. Although interference of the reactions due to the horizontal components of the cutting force with the true vertical component can be greatly reduced by electrically cancelling these reactions, complete cancellation is possible only if the sensitivity of the bridges is identical. Due to variations in the gauge resistances, the gauge factors and some small difference in the rings themselves, slightly different bridge outputs would result under equal loads. This would only partially cancel the unwanted outputs and would not completely eliminate the interdependence of the vertical bridge output on the horizontal component—an undesirable feature of any dynamometer. Hence a provision for equalising the sensitivity of all bridges separately becomes important.

The balancing system for the bridge was designed to provide a coarse and a fine control. High stability carbon resistors in conjunction with wire-wound potentiometers were used to minimise errors due to drift, etc.

The complete electrical circuit shown in Fig. 8 was designed to cater for all the requirements listed above. Selector switches of the rotary wafer type having a contact resistance of less than .003 ohms are used. The current in each bridge can be read on a milliammeter by inserting the jack plug into any of the eight monitor sockets. Sensitivity control for the bridge is provided by a 50 ohms linear wire-wound potentiometer.

With the moving coil galvanometer, used for balancing the bridges, a more accurate balance can be achieved than with the oscilloscope.

By means of the vertical selector switch the four vertical bridges can be either connected in

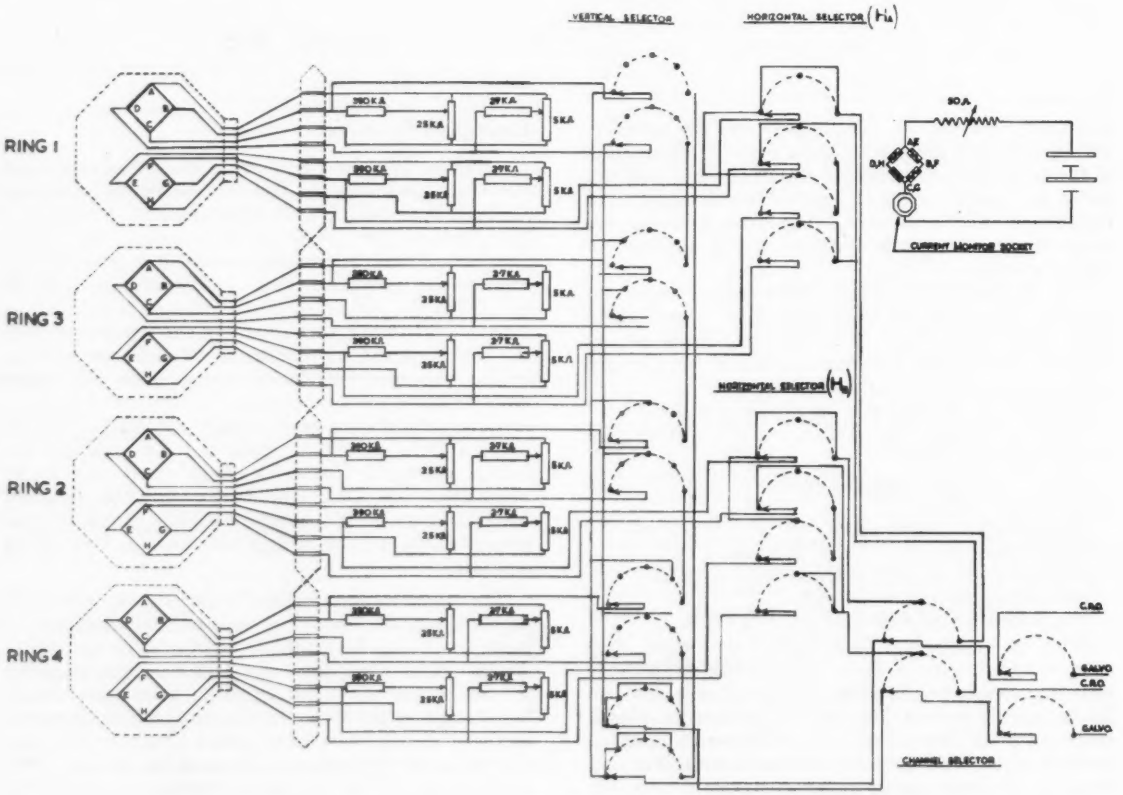


Fig. 8.

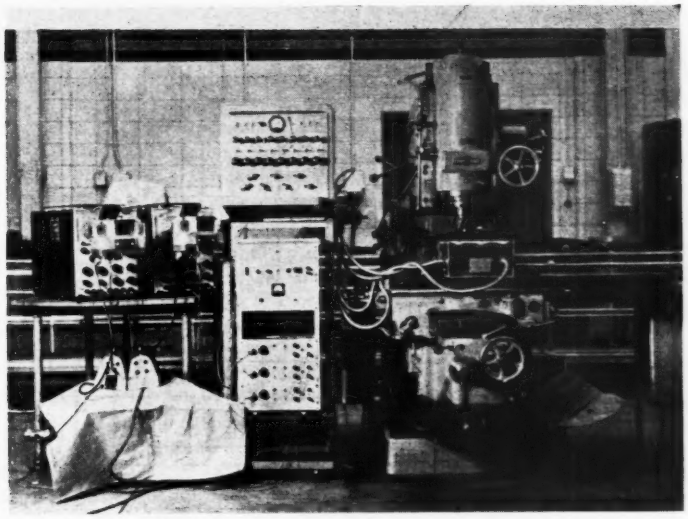


Fig. 9.

series or the output of any of them can be selected. The two horizontal selector switches serve a similar purpose for the bridges which are sensitive to the horizontal components of the cutting force. With the circuit selector switch any of the three force components can be selected whilst cutting is in progress. This is necessary because at the beginning of the tests only a single channel oscilloscope was available and all three components of the cutting force had to be recorded on this channel.

In subsequent experiments, two twin-beam Solartron type CD.711 oscilloscopes were used and instantaneous recording of all three components was obtained. The two cameras for the oscilloscopes were synchronised and controlled by a single switch. The circuit selector switch was made inoperative. In both cases, a 50 cycle wave on the oscilloscope served for timing purposes.

Sixteen 2-volt Exide accumulators are used for the power supply. The output from the bridges is amplified 100 times by a Southern Instruments Type MR235 D.C. pre-amplifier which is equipped with a drift correction circuit. The measured noise level of this amplifier was found to be 0.030 mV.r.m.s. referred to input, which is just low enough for recording the smallest output voltages from the bridges.

The control panel is so arranged that the wires from the strain gauge terminals on each ring are conducted through flexible metal conduits to a terminal board on which the ring and strain gauge numbers are marked for identification.

Complete electrical screening and earthing of the whole system eliminates any pick-up in the signal. The electrical connections are enclosed within a sheet-metal casing and the battery bay is similarly screened.

The dynamometer and the panel stand which contains the amplifiers and the batteries thus form compact easily transportable units. The complete set-up of the dynamometer with the control panel and the recording equipment is shown in Fig. 9.

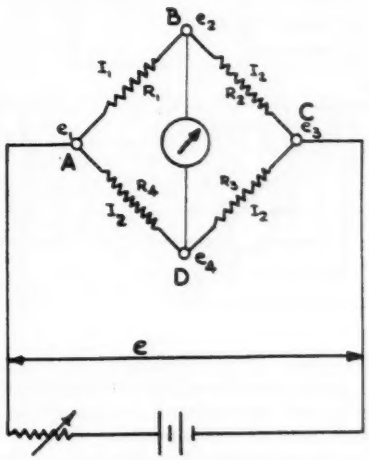


Fig. 10.

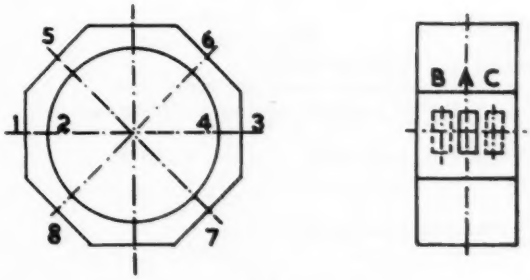


Fig. 11.

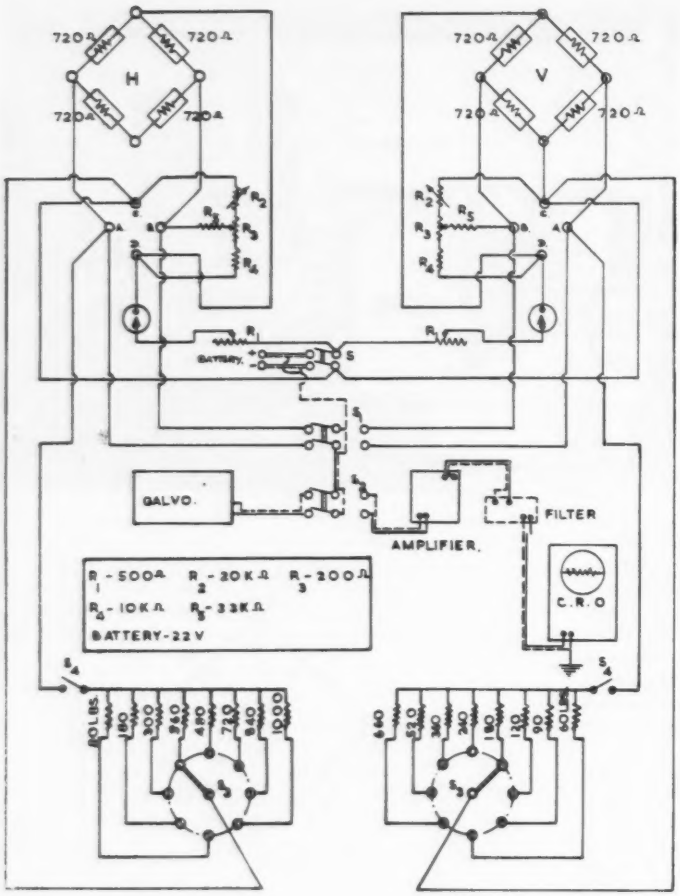


Fig. 12.

The sensitivity of the dynamometer depends upon the strain gauges and the electrical amplification used. As stated earlier, the choice in favour of the 120 ohm gauges was entirely influenced by their small grid size. If a vertical force V = 40 lb. is applied to the dynamometer, the total output of the four bridges in series can be calculated and from that the shift of the trace on the oscilloscope obtained as follows:—

In the bridge (Fig. 10) all four arms are active, and

$$e_2 - e_4 = \frac{e\,\delta Rg}{Rg} \qquad (2)$$

also $\delta Rg = G \cdot \varepsilon \cdot Rg$

where G = gauge factor

ε = strain under the given load

Rg = nominal resistance of the gauge.

$$\text{Load on each ring} = \frac{40}{4} = 10 \text{ lb.}$$

$$\text{Strain on each gauge } \varepsilon = \frac{0.7\,VR}{E\,Wt^2}$$

$$= \frac{0.7 \times 10 \times 1.5}{30 \times 10^6 \times 1.5 \times 0.09} = 0.0000026.$$

For the resistance wire strain gauges used,

G = 2

Rg = 120 ohms

and $R_1 = R_2 = R_3 = R_4$ (unstrained).

The current chosen for each gauge = 12.5 mA.

$e = I_1 (R_1 + R_2)$

$= 12.5 \times 10^{-3} \times 120 \times 2 = 3$ volts.

Substituting values in Equation 2

$$e_2 - e_4 = \frac{3 \times 2 \times 0.0000026 \times 120 \times 4}{120}$$

= 0.0000624 volts (for all bridges sensitive to vertical load).

The pre-amplification used gives a gain of 100.

Hence the input voltage of C.R.O. = 6.24 mV.

Now 1 mV. input to the C.R.O. shifts the trace along the Y axis by 0.29 mm.

Hence the shift of the trace for an input voltage of 6.24 mV. is 1.8 mm.

The dynamometer is, therefore, sensitive enough to enable a vertical force of 40 lb. to be recorded.

At first sight it may appear that the sensitivity of recording can be improved further if the number of strain gauges is increased, e.g., by positioning them at A, B and C along the width of

the ring (instead of at A alone) as shown in Fig. 11. In this case, the number of active gauges in each arm of the bridge would be three and the sensitivity could be increased three-fold. However, a force acting parallel to the axis of the ring would subject gauge C to compression and gauge B to tension or *vice versa*. Small variations of the gauge factors and gauge resistances, as well as slight inaccuracies in placing gauges B and C in relation to the neutral axis would therefore result in only partial cancellation of the bridge outputs. The result would be a net output due to a horizontal force from gauges which should be sensitive to a vertical force only, and this would tend to introduce an undesirable interference effect in the recording of the three components of the cutting force.

Two-Dimensional Dynamometer

The two bridges for the horizontal and the vertical loads are connected as shown in the diagram (Fig. 12). The bridge circuits are incorporated in a box.

Each face of the dynamometer ring carries six gauges of 120 ohms. These are connected in series so that the overall resistance on each face is 720 ohms, thus increasing the voltage and hence the sensitivity sixfold. This is, of course, based on the assumption that the stress is uniform over the width of the ring, an assumption which, due to the negligible axial component of the cutting force, appears permissible.

It was found that for an overall gain of 135,000, i.e., 1,500 from the amplifier and 90 from the oscilloscope, the pick-up and noise level could be considered satisfactory.

The timing marks on the oscilloscope screen are obtained by modulating the intensity of the two beams of the oscilloscope by means of an oscillator. The beams appear dotted and by counting the number of dots over a certain period, the time interval, and thus the frequency of the particular phenomenon can be determined.

A simple ' band elimination ' filter was also designed to attenuate those harmonics which were in the vicinity of the natural frequency. The filter allowed, without hindering, waves of frequencies outside the eliminated band to pass.

The filter is arranged between the amplifier and the oscilloscope. A terminating resistance ' R ' serves for obtaining high attenuation as well as sharp cut-off.

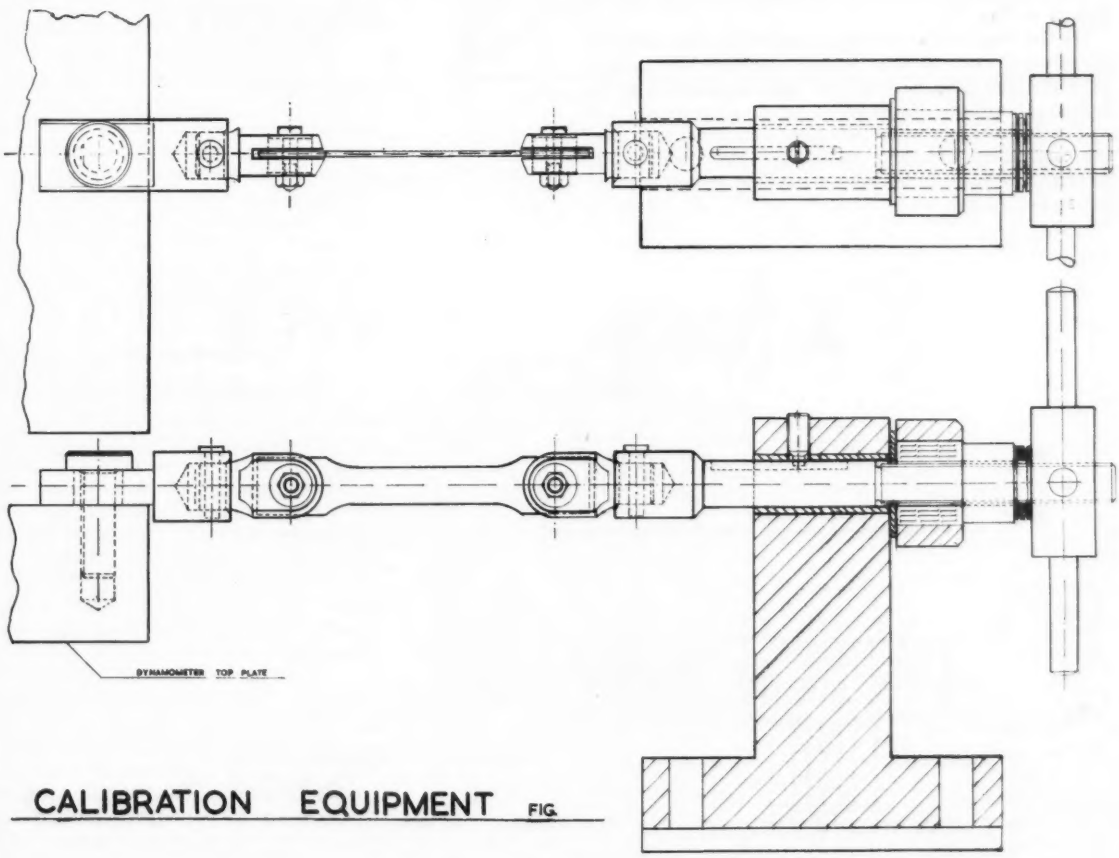


Fig. 13.

Static Calibration

Three-Dimensional Dynamometer

A general arrangement of the equipment designed for applying a horizontal calibrating load is shown in Fig. 13. A weigh bar is connected to the dynamometer at one end and pulled by a nut and thread arrangement at the other. The elongation of the weigh bar is recorded by means of a Hounsfield extensometer. As the weigh bar had previously been calibrated the elongation of the bar gives a measure of the applied load.

The vertical calibrating load is applied by the hand feed of the milling machine spindle through a calibrating ring.

Checks were carried out to ensure that the bridges sensitive to one component of the cutting force were insensitive to forces applied along directions of the other two force components. Fig. 14 shows the effect of a horizontal force H_A on bridge outputs sensitive to components of the cutting force along V and H_B. The effect of a vertical force on the bridges sensitive to components along H_A and H_B was found to be of similar small magnitude.

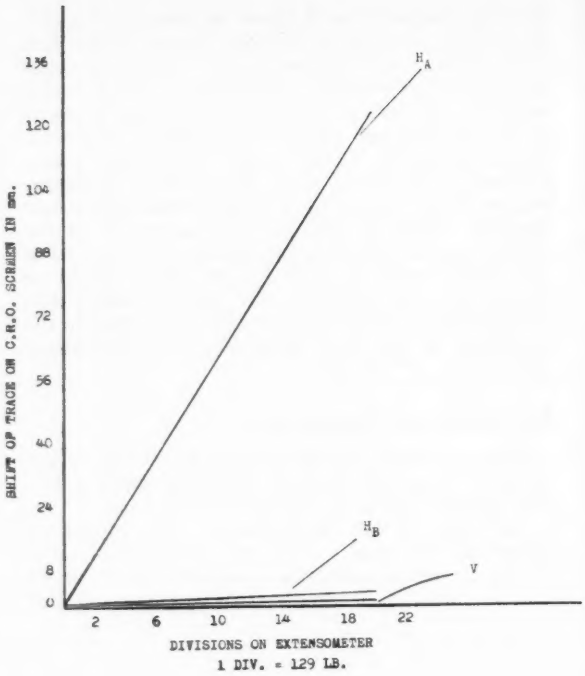


Fig. 14.

Two-Dimensional Dynamometer

The special calibration rig using dead weights is shown in Fig. 15.

As the amplifier and the gauges take some time to stabilise, a current was passed through the gauges with the amplifier switch ' on ' for about 30 minutes, before taking any readings.

The two bridges were calibrated independently and corresponding readings taken on the oscilloscope screen. Calibration curves for loading and unloading are shown in Fig. 16.

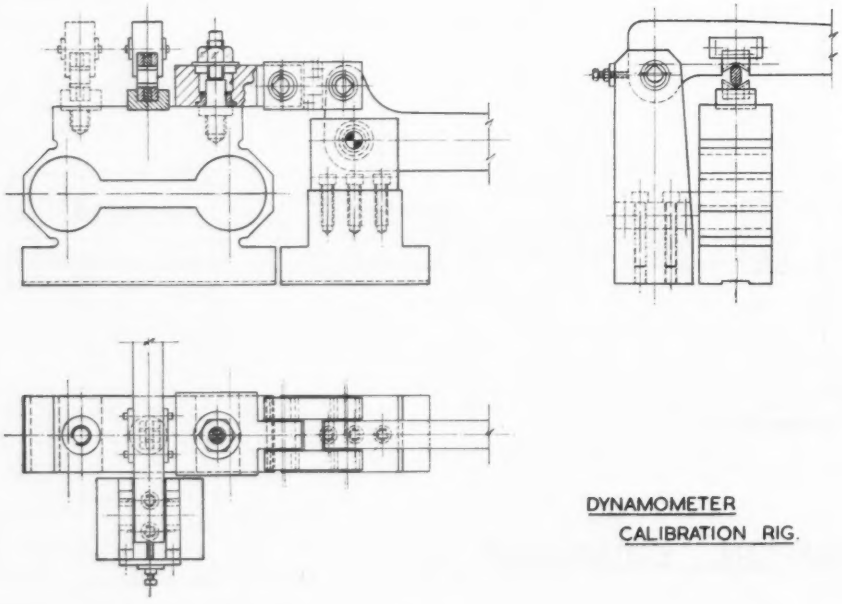


Fig. 15.

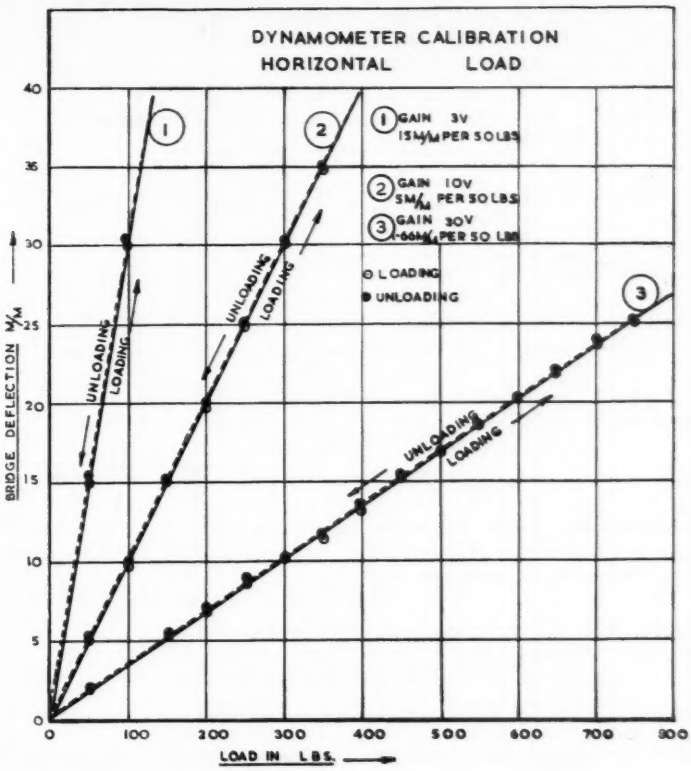


Fig. 16.

The vertical load was applied both in the centre and eccentrically on the top plate, and it was confirmed that the dynamometer worked independent of the point of application of the load.

The amount of cross-interference between the two bridges under loads was also checked and found to be of the order of one to two per cent.

For a day-to-day check of the calibration it was not possible to apply dead weights and for this purpose calibration resistors were provided. These could be switched across one arm of the bridge and were initially calibrated by noting the amount of out of balance caused by each resistor. This out of balance was evaluated in terms of load in lb. and formed a secondary calibration.

Dynamic Calibration

Three-Dimensional Dynamometer

A vibration generator provided sinusoidal excitation. The frequency could be increased without changing the amplitude of the applied vibration and the graph of amplitude output against frequency (Fig. 17) shows that a constant amplitude output was obtained up to a frequency of 50 c/s. Above that frequency two small peaks appeared at 120 c/s. and 180 c/s. and then a major resonant frequency at 250 c/s. To confirm that this is the natural frequency in the horizontal plane, the dynamometer was set into vibration by a hammer blow and an oscillographic record of the strain gauge output was obtained. This also showed the natural frequency to be 250 c/s. The natural frequency in the vertical direction was found to be 650 c/s.

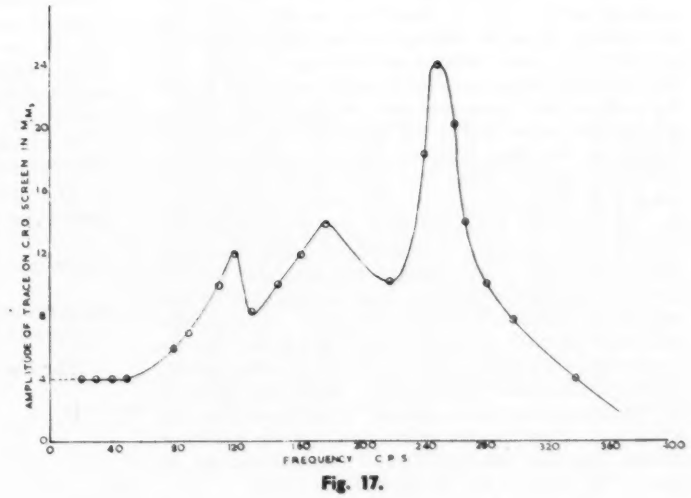


Fig. 17.

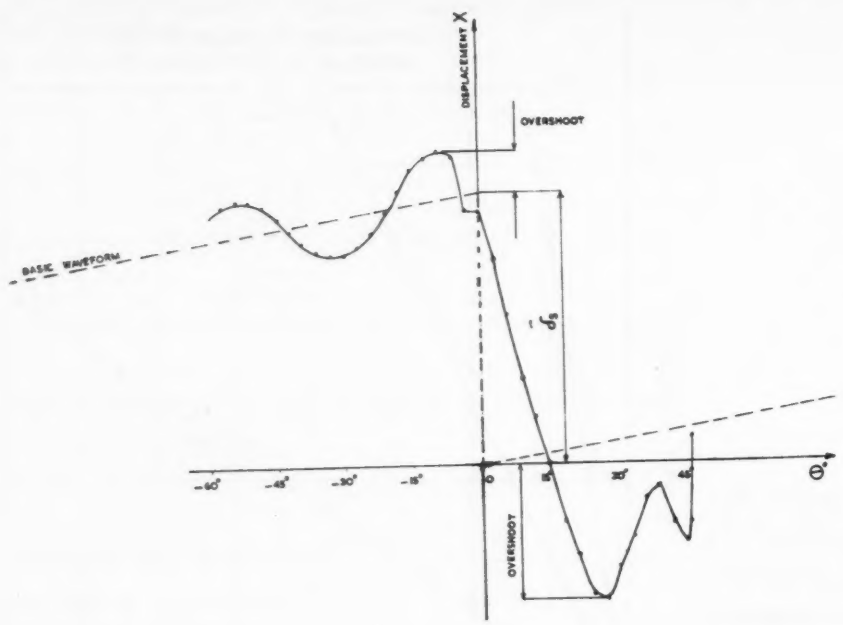


Fig. 18.

The dynamic magnifier D at resonance in the horizontal plane calculated from the decay curve was found to be 5.042. The value of D = 6 obtained from the resonance curve (Fig. 17), being the less favourable of the two, is used for all subsequent calculations.

The existence of the small peaks in the resonance curve may be explained by the vibration of those parts of the machine structure which were excited at their own resonant frequency thereby increasing the amplitude of vibration of the dynamometer.

The machine spindle had so far not contributed to the excitation of the dynamometer. The effect of the working parts of the machine as a whole (including the spindle) upon the dynamometer was investigated by putting a plate cam to the machine spindle, the cam follower being a roller bearing mounted to the top-plate of the dynamometer. A brass liner lightly gripped the outer race of the roller bearing and short flanges on the liner kept the outer race in position. The cam had 24 lobes and their form was nearly sinusoidal. With the cam and the follower in position, the load on the dynamometer could be easily increased by traversing the machine table by hand against the cam. By rotating the machine spindle slowly by hand, the applied load was gauged by the maximum shift of the oscilloscope beam. The spindle was then allowed to rotate under power at varying speeds and the shift of the oscilloscope beam noted. It was found that the constant amplitude limit of the dynamometer was reduced from 50 cs./sec. to 35 cs./sec. This appears to indicate that the influence of the machine structure could be ignored up to nearly 35 cs./sec. for sinusoidal excitation.

In practical milling operations, the cutter teeth do not, however, impart true sinusoidal vibrations to the dynamometer.

The fluctuation of the milling force as a function of time may be approximated to a triangular form in which the slope of the two sides depends on the geometry of the cutter used and the depth of cut. In order to impose the severest conditions upon the dynamometer and assess its performance under these conditions the drop of the peak force was considered a sudden one. The effect of the harmonics upon the dynamometer response and the distortion of the original waveform can be determined by an analysis of the saw-tooth waveform, taking into account its harmonics up to and including the seventh. The value of the seventh harmonic for a cutter with eight teeth and a spindle speed of 270 r.p.m. is 252 c.p.s. This is almost synchronous with the natural frequency of the dynamometer.

The purpose of the harmonic analysis was to determine the contribution made by each of the seven harmonics considered for the function $f(x) = \frac{x}{2\pi}$ towards the total amplitude of vibration produced by a given forcing frequency.

The dynamic magnifier D_n is given by

$$D_n = \frac{1}{\sqrt{\left[1 - \left(\frac{n_n}{n_d}\right)^2\right]^2 + \left(K\,\frac{n_n}{n_d}\right)^2}} \qquad (3)$$

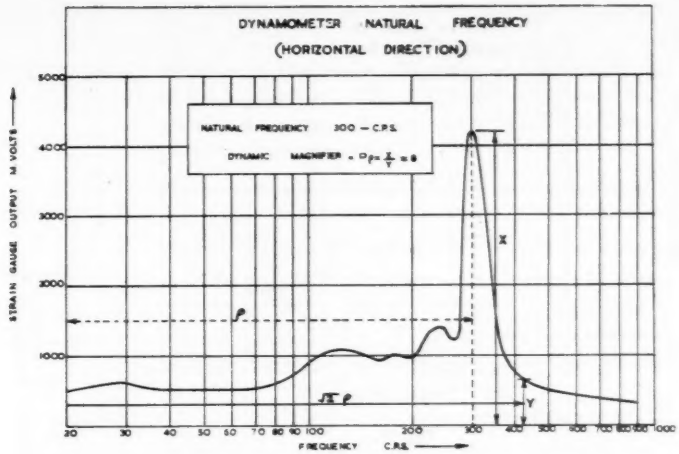


Fig. 19.

where n_n = frequency of the harmonic considered
n_d = natural frequency of vibration of the dynamometer
K = spring constant

K is calculated from

$$D_{250} = 6$$

hence $$6 = \frac{1}{\sqrt{K^2}} \quad \text{or} \quad K = \frac{1}{6}.$$

$$X_n = \delta_s \times D_n \times A_n \times \text{Sin}(n\,\omega t - \varphi_n)$$

where X_n = contribution towards the displacement of the dynamometer by the n^{th} harmonic, at angle $\theta = \omega t$ traversed by the milling cutter tooth along its path.
δ_s = the static deflection of the dynamometer at angle $\theta = 2\pi$.
φ_n = the phase lag between the applied force and the displacement.
A_n = coefficient for the n^{th} harmonic of the Fourier series.

$$\varphi_n = \tan^{-1} \frac{K \frac{n_n}{n_d}}{1 - \left(\frac{n_n}{n_d}\right)^2}$$

A more generalised expression for X_n was obtained by taking $\delta_s = 1$. Values of X_n were thus obtained as ratios which could be applied to δ_s of any magnitude.

The displacement curve plotted (Fig. 18) shows the extent of overshoot of the dynamometer at each end and the distortion of the basic waveform.

The ideal condition for producing an undistorted picture of the force wave, could only be obtained with a dynamometer of infinite rigidity. In the present example, the dynamic magnifier for the eighth harmonic is 2.2 and the contribution of this harmonic towards the displacement of the dynamometer is $2.2 \times \frac{1}{8} \times \frac{1}{\pi}$ i.e., 8.7 per cent of δ_s and this was considered permissible.

In the above analysis, the saw-tooth waveform coupled with the particular spindle speed and the

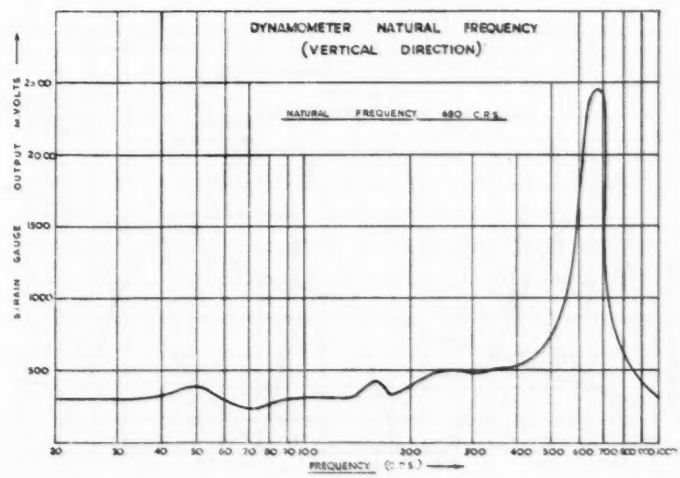


Fig. 20.

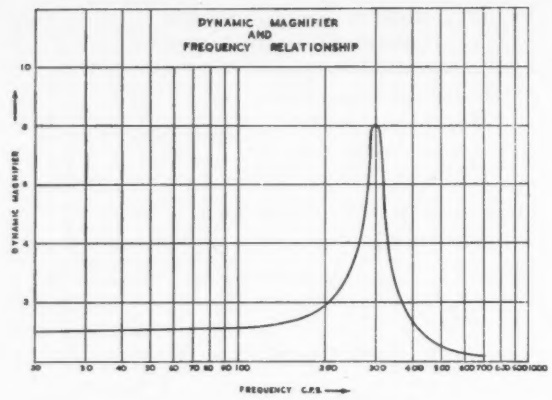


Fig. 21.

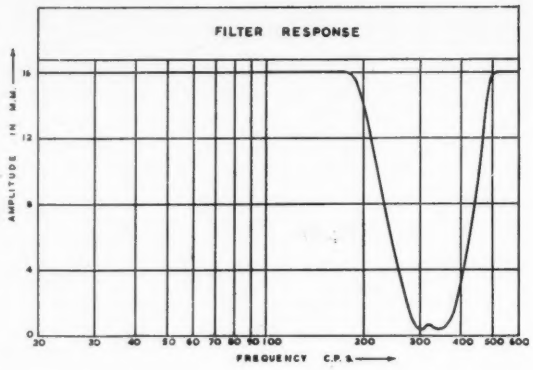


Fig. 22.

number of teeth in the cutter produces very unfavourable conditions. With a helical cutter, the force fluctuations are not as abrupt as the saw-tooth form analysed above, and conditions will be more satisfactory.

Two-Dimensional Dynamometer

A pulsating excitation force of fixed amplitude was again applied at a variable frequency by means of a vibration generator.

From the resonance curves (Figs. 19 and 20) the values of the natural frequencies were obtained, because due to low damping these were practically equal to the resonance frequencies.

The slight fluctuations in the working range of the resonance curves are again considered due to the interference effects of some members of the machine.

The dynamic magnifier at any frequency is given by Equation 3 and is plotted against frequency in Fig. 21.

The characteristics of the filter (see page 736) were tested by passing a known signal at a known frequency by means of an oscillator through the filter-amplifier combination and noting the output by means of a phase-meter. The attenuation constant of the filter was found to be very high in the ' eliminated bands ' and negligible in the ' transmitted bands ' (Fig. 22). When not required, the filter can be by-passed and the signal taken straight to the oscilloscope.

The dynamic magnifier relationship shows that up to about 75 cs./sec., i.e., about a quarter of the natural frequency, the output signal under the harmonic force is magnified less than about five per cent. Responses with and without the filter were plotted against frequencies corresponding to a cutter with 14 teeth revolving at 50, 250, 350, 450, 550 and 750 r.p.m., i.e., 11.6, 58.4, 81.7, 105, 128.3 and 175 c.p.s. When the dynamic magnification became too high, the signal was passed through the filter so that the higher harmonics were attenuated and

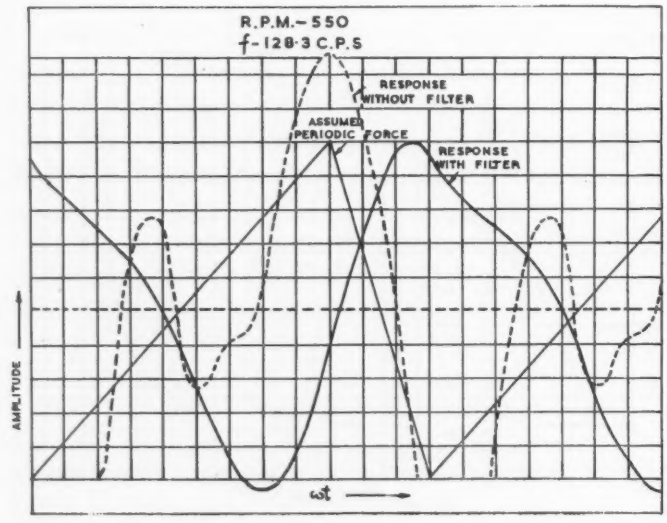


Fig. 23.

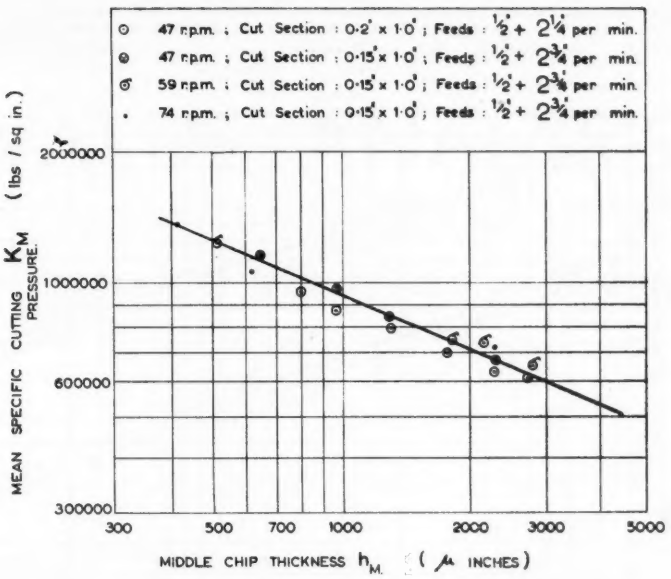

47 r.p.m. ; Cut Section : 0·2" x 1·0" ; Feeds : ½" + 2¼" per min.
47 r.p.m. ; Cut Section : 0·15" x 1·0" ; Feeds : ½" + 2¾" per min.
59 r.p.m. ; Cut Section : 0·15" x 1·0" ; Feeds : ½" + 2⅞" per min.
74 r.p.m. ; Cut Section : 0·15" x 1·0" ; Feeds : ½" + 2¾" per min.
MEAN SPECIFIC CUTTING PRESSURE K_M (lbs / sq in.)
2000000
1000000
600000
300000
300
500
700
1000
2000
3000
5000
MIDDLE CHIP THICKNESS h_M (μ INCHES)

Fig. 24.

the amplitude of the signal showed little if any dynamic magnification (Fig. 23).

Due to the phase shift and the attenuation, the normal Fourier series had to be modified in order to allow for the phase angles for the particular harmonic through the filter-amplifier combination and for the attenuation factors.

At frequencies above a quarter of the natural frequency the response curves must, therefore, be very carefully studied. The error introduced by the dynamic magnifier at lower frequencies does not appear to be serious and below about a quarter of its natural frequency the dynamometer can be used without a filter.

Cutting Tests

The following cutting tests were carried out in order to try the application of the dynamometers.

1. *Tests on High Tensile Steel*

Three-dimensional dynamometer.
Material cut — D.T.D.331 (80 tons/sq. in. Ni-Cr. Steel).
Milling cutter — Side and Face Cutter (H.S.S.)
Diameter—2½ in.
Radial rake—7½°.
Axial rake—7½°.
Helix angle—30° R.H.
Number of teeth—8.

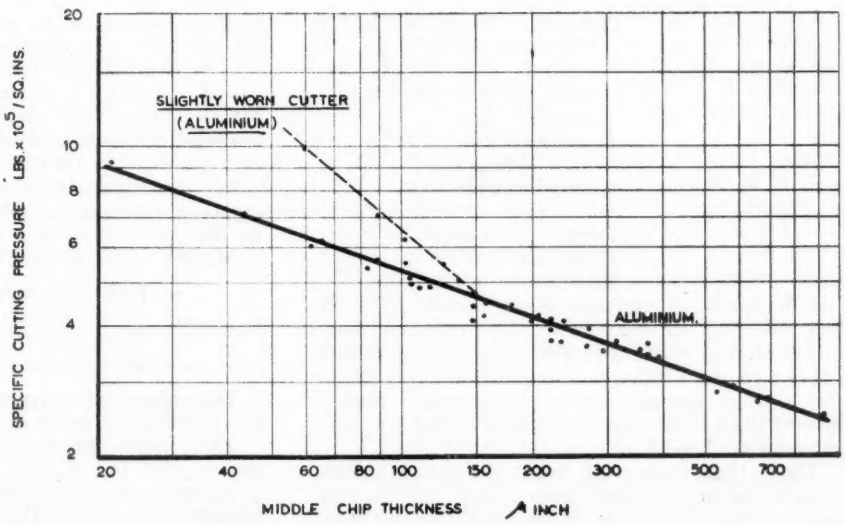


Fig. 25.

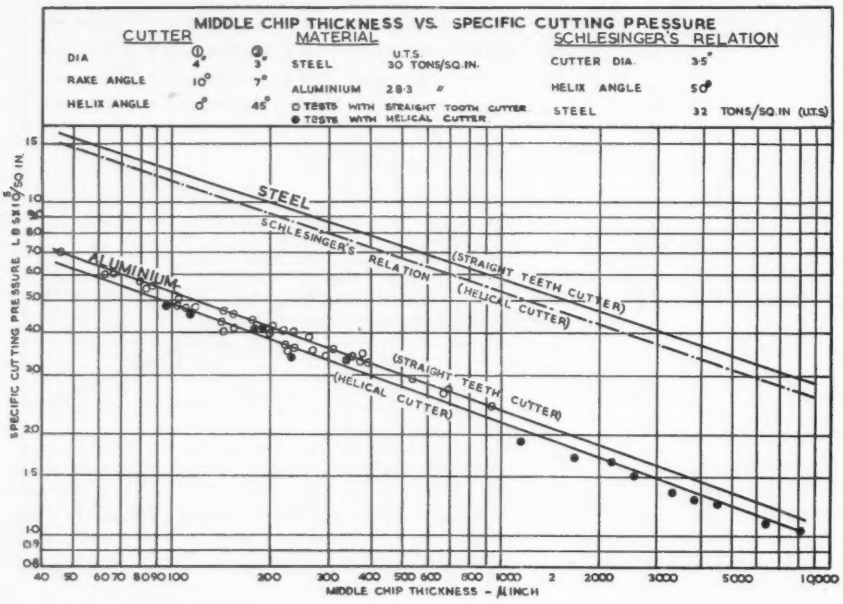


Fig. 26.

The average specific cutting forces obtained from these tests plotted against the middle chip thickness in a log-log system.

$$h_m = \frac{s^1}{nZ}\sqrt{\frac{a}{d}\left(1 - \frac{a}{d}\right)}$$

lie well on a straight line (Fig. 24).

s^1 = feed per min.
n = r.p.m. of machine spindle.
Z = number of teeth of cutter.
a = depth of cut.
d = diameter of cutter.

2. *Tests on Light Alloy*

Two-dimensional dynamometer.
Material cut — Light Alloy "Noral 26 S.W.P." (28 tons/sq. in. U.T.S.)
Milling cutter — Standard High Speed Steel Side and Face Slab Cutter (see Fig. 2).
Diameter—4 in.
Width—$\frac{7}{8}$ in.
Number of teeth—14.
Rake angle—10°.
Primary clearance—1°.
Helix angle—0°.
Eccentricity $\pm$ 0.0002 in.

From results of tests with spindle speeds of 74, 93, 125, 186, 232, 310, 465, 580 and 775 r.p.m., and feeds of $1\frac{1}{2}$, $3\frac{1}{2}$, $4\frac{7}{16}$, 6 and 8 in. per minute and depths of cut of 0.05 in., 0.10 in., 0.15 in., 0.20 in. and 0.25 in. the average specific cutting force values plotted against the middle chip thickness in a log-log system are shown in Fig. 25.

The cutting forces, and hence the energy values, grow as the cutting edges become worn and this may happen even if only one of the teeth becomes dull. After a certain number of tests the specific cutting force values appeared to lie on a steeper line (see Fig. 25). It was assumed that this was due to a decrease in the sharpness of some or all of the teeth of the cutter.

This assumption appears to be justified, because after the cutter was reground and the tests were repeated the results fell within the range of the curve drawn for the original tests.

With increasing chip thickness, the effect of dulling was less pronounced and hence it may be suggested that the energy values with thick chips are less affected by variation in cutter sharpness than those with thin chips.

Tests with 0.23% carbon steel (30 tons/sq. in. U.T.S.) carried out at spindle speeds of 38, 50, 74, 93, 125, 186 r.p.m., depths of cut of 0.05 in., 0.10 in., 0.15 in., 0.20 in. and 0.25 in. and feeds of $\frac{15}{16}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $2\frac{5}{8}$, $3\frac{1}{2}$ and $4\frac{7}{16}$ in. per minute showed average specific cutting forces in remarkable agreement with results of tests with a helical tooth cutter (helix angle 50°) published in 1931 by Schlesinger[1] (Fig. 26).

For this reason, tests using the three-dimensional dynamometer were carried out with a helical cutter on the before-mentioned light alloy.

Milling cutter specifications:

Cutter diameter — 3 in.
Width of the cutter — 3 in.
Rake angle — 7°.
Helix angle — 45°.

The values of the tangential component were found by resolving the forces in the appropriate directions.

The values of the specific cutting pressure appear to be slightly lower for the case of a helical cutter than those found for that of the straight teeth cutter (Fig. 26). The difference does

(*concluded on page* 769)

VALUE ANALYSIS

A Specialist Approach to Cost-reduction in Industry

by J. RAWICZ-SZCZERBO,

M.Sc., Grad.I.E.E., Grad.I.Prod.E.

Mr. Rawicz-Szczerbo was born in Warsaw and in 1940 came to England, where he was educated at Stonyhurst College. He took the University of London degree of B.Sc. in Electrical Engineering in 1952 at the City and Guilds College.

He served a graduate apprenticeship with The General Electric Company Ltd., Witton, where he was subsequently employed, first in the Value Analysis Section (Production Engineering Department) and later as Section Superintendent in the F.H.P. Motor Works. In 1955, he was sponsored by G.E.C. to take his M.Sc. in Engineering Production and Management at the University of Birmingham. He is now Superintendent of the Small Motor Department of The General Electric Company Engineering Works.

Mr. Rawicz - Szczerbo presented this Paper on "Value Analysis" to the Birmingham Graduate Section of The Institution of Production Engineers on 12th November, 1957.

IN order to be desirable, a product must satisfy a particular need, fulfil its function efficiently, and attain an acceptable standard of quality. To be successful, however, it must also be produced at a cost which is well within the financial means of its potential market.

The steadily rising costs of material and labour have long focussed a great deal of attention on proper material selection and on higher manufacturing efficiency. While the design departments of many concerns have been instructed to concentrate on reducing the material content of their products, the manufacturing divisions have developed more effective production methods. The phenomenal growth of interest in work study and production engineering since the War is an indication of the emphasis placed on improving manufacturing efficiency.

More recently, however, there has also been an increasing recognition of the fact that production costs are as dependent on good design for production, as they are on material economy and manufacturing competence. This has been realised in the United States sooner and more widely than in Britain, as is indicated in the British Productivity Council Report on "Design for Production".

While it is logical that a thorough attack on costs should begin at the earliest design stages of product development, it is unfortunately true that most engineers and draughtsmen have hitherto had little experience or formal training in the factors which affect manufacturing costs. As a result, many design decisions which have a profound effect on product costs may be based on out-dated experience and opinion. This sad state of affairs is due to two causes :-

(i) the traditional preoccupation of technical departments with performance and quality, and

(ii) a lack of up-to-date facts and ready sources of information on which the designers may draw.

I must emphasise that this is *not* intended to suggest that designers are in any way *unwilling* to consider costs; in many cases they are *unable* to do so effectively.

The problem of ensuring competent design for production has been tackled by leading companies in a variety of ways; most of these consist of some form of committee or team at which management, design, production and sometimes commercial groups are represented. These committees meet regularly to co-ordinate the requirements of all these groups with the object of securing the proper balance between performance and costs.

While these methods ease the problem, in most cases they do not solve it fully. Companies employing these procedures have found that potential for further cost-reduction still exists. L. D. Miles, Manager of the Value Analysis Service Section of the General Electric Company of America, read a Paper before the American Society of Mechanical Engineers, in 1953, in which he stated [2] :-

> "On the average, one-fourth of manufacturing cost is unnecessary. The extra cost continues because of patterns and habits of thought, because of personal limitations, because of the difficulties in promptly disseminating ideas, and because today's thinking is based upon yesterday's knowledge."

This rather sweeping statement may be an expression of opinion, but it was based, at the time of speaking, on six years' specialist cost-reduction activities which were saving General Electric literally millions of dollars annually. Bruce Payne, the President of the Society for the Advancement of Management, made a similar statement at about the same time [3] :-

> "Practically every company in the United States today can cut its cost of production at least 10%. Actually, most companies, whether large or small, new or old, in high profit industries or low, could cut their costs a great deal more — 15%, 25% or 40% — and in not too long a time."

One way in which this cost reduction can be approached is through Value Analysis. The name has been adopted by the General Electric Company of America, to describe a specialist activity whose aim is to secure equal or better quality of the product at the minimum cost. Other companies have either followed this example or developed similar activities on their own. All claim a high degree of success.

This Paper sets out to define what Value Analysis is, to describe how it functions and what it has achieved. It is based on an investigation which the author carried out for the Department of Engineering Production at Birmingham University. The investigation covered the practice adopted by four American and three British organisations of different sizes, in the engineering and allied industries.

Before describing in detail what Value Analysis is and what it can and does do, I think it may be of interest to consider a few examples of what has been achieved in several organisations by the use of this technique :-

(i) The General Electric Company of America, as I have already indicated, has been saving several million dollars annually, over the last 10 years.

(ii) The United States Navy, which established a Value Analysis Department three or four years ago, saved over $18,000,000 in the first year and greater amounts since.

(iii) Caterpillar Tractor Company is saving something like $1,500,000 annually.

(iv) A smaller Company, The A. C. Gilbert Company, manufacturers of electrical, mechanical and chemical toys, employing some 2,000 people, claim to be saving over $100,000 per year.

(v) In Great Britain, The Joseph Lucas (Electrical) Co. Ltd. reports savings of between £70,000 to £100,000 annually.

(vi) In the General Electric Co. Ltd., at Witton, during the last year of fairly intensive application of this technique in the Fraction Horse Power Motor Factory, savings have been achieved which are, at the moment, running at the rate of £37,000 a year, and this on products which, in the most part, had already been well designed for production.

These and other organisations report a return on the investment made in Value Analysis, of something between 10 to 1 and 20 to 1.

The investment consists, for instance :-

(i) in the case of General Electric of America, of a Central Value Analysis Section of seven specialists, and Value Analysis Units in 38 of its 130 factories, staffed by a total of 84 engineers. In addition, over 3,000 engineers have been trained in Value Analysis techniques since 1952 in frequent three-week courses run by the central section.

(ii) The U.S. Navy has a central section of 12 engineers and field units in all the 11 naval shipyards staffed by 55 engineers.

(iii) The A. C. Gilbert Co. employs four engineers on Value Analysis.

(iv) Joseph Lucas and the F.H.P. Works of the aid of only one Value Analyst apiece.

These results are spectacular, but it is hoped they will not lead anyone to suppose that Value Analysis is claimed to be the answer to all troubles. It is not. Neither do these results indicate any excessive inefficiency on the part of the firms trying this technique,

for they are among the leaders in their fields and are generally acknowledged as such.

Nevertheless, Value Analysis is a powerful tool; and like all good tools, properly used by the right people in the proper circumstances, it works very well indeed.

object

The object of Value Analysis is to obtain cheaper products of the *same* or *better quality*. It is called *Value Analysis* because it does not seek merely cost reduction for its own sake, but better value for money. In this context, value can be defined as the relationship between function and cost, so that in determining the value of a component or material it is important to consider what it does or is expected to do. For example, if we buy steel all we may want is mechanical support; in buying a screw all we may want is a method of fastening — a rivet may do just as well; paint is specified as surface protection and appearance, copper for electrical conductivity.

An American source provides a more graphic illustration of this and I will quote is 2 :-

> "The value of Miss Hollywood, bathing in the California sunshine, is not established by a chemical analysis of her blood and bones, but by direct comparison with the Misses to her right and to her left, comparing the abilities of each to please the eye, the imagination and the sponsor."

Value is thus established by the comparison of the need with the cost. As such it is a matter of interpretation, judgment and decision by the person responsible either for providing a product or a service or for selecting it. So many diverse factors must come together to influence the judgment that it is doubtful whether objective measures of value as such can ever be set up. The final arbiter will always be the customer; and the standard will be whatever he is prepared to buy and at what price. Industry, dependent for its success on its efforts to supply products that are desirable, has a vital interest in ensuring that the ratio of function to cost is at the maximum attainable levels.

method

The method of Value Analysis is to study those features which contribute to cost of any material, component, operation, process, or product, in order to determine whether they are fulfilling their functions economically, or whether those functions can be performed more cheaply by some other means.

A great deal of work has been done in developing methods and techniques for Value Analysis that are both effective and capable of being demonstrated convincingly for training purposes. Many examples of these techniques have been published in recent years, particularly in the U.S.A.

Value Analysis demands a thorough systematic approach.

This involves five stages .-

Stage 1 — *Information*

All facts about the product must be collected -- i.e., drawings, specification, manufacturing methods, quantities, sources of supply and accurate costs.

The product is discussed in detail with any person directly interested in it, in order to get a true appreciation of its function. Particularly it must be discussed with the designer in order to get an insight into its proposed future development. This stage is the most important of the five.

Stage 2 — *Analysis*

This consists of identifying the functional areas into which all the components fall (for example, whether it is a fastening job, a surface protection job or a support job), and also deciding whether the components are worth their cost. Obviously here the experience of the analyst plays a very important part.

Stage 3 — *Speculation*

At this stage ideas for cheapening the product are generated and collected together.

The specialists in the functional areas into which the components fall are consulted and their ideas are sought. This is done not only inside the company but also outside, if this is possible.

Questionnaires are used for obtaining ideas and for ensuring that nothing is overlooked; examples of these will be given a little later.

Stage 4 — *Investigation*

At this stage ideas which have been generated are analysed, in order to ascertain whether they will work and whether they will actually save money. Those which are obviously unacceptable are scrapped, and the doubtful ones are referred for testing.

Stage 5 — *Conclusion*

A report is prepared on the worthwhile suggestions, listing any savings to be made and this report is sent to all the executives dealing with the product examined and all decisions are then left to them.

I have mentioned that questionnaires and possibility guides are used in the Speculative Stage. It is impossible to demonstrate the detailed ones here, but I have reproduced in Fig. 1 the "Ten Tests for Value" applied by General Electric. These are widely issued within the Company in the form of attractively printed certificates.

examples

Now I would like to explain the thoughts behind these questions :-

(i) *Does its use contribute value ?*

(ii) *Is its cost proportionate to its usefulness ?*

(iii) *Does it need all its features ?*

TESTS FOR VALUE
Our Challenge—Our Obligation
Every material, every part, every operation must pass these tests
★ ★ ★
1. Does its use contribute Value?
2. Is its cost proportionate to its usefulness?
3. Does it need all of its features?
4. Is there anything better for the intended use?
5. Can a usable part be made by a lower cost method?
6. Can a standard product be found which will be usable?
7. Is it made on proper tooling—considering quantities used?
8. Do material, reasonable labor, overhead and profit total its cost?
9. Will another dependable supplier provide it for less?
10. Is anyone buying it for less?
VALUE ANALYSIS SERVICES
GENERAL ELECTRIC

Fig. 1.

These three questions are concerned with the purpose of the part, i.e., its function, and they seek to eliminate or simplify it or combine it with another part. This is fundamental. If a function can be performed more economically in another way, there is no reason for attempting to make or buy it cheaper.

(iv) *Is there anything better for the intended use?*

This question focusses attention on new materials or processes which may have been developed since the product was first made. Perhaps at that time, for instance, a shortage of the best material, which now may be more plentiful, caused substitutes to be used.

(v) *Can a usable part be made by a lower cost method?*

Here attention is drawn to the present method used — whether a component is bought outside or not. This method is obviously determined by drawing specifications and tolerances, by the output quantities, by the machines or tools available at the time or by the need to get into production quickly and, therefore, to accept something that is not ideal, purely to save time.

Analysis on this line of thought can show that changes in any of these specifications or conditions may allow quicker methods to be employed. In the case of components supplied from outside, it may be more difficult to ascertain exactly what methods are used and co-operation of the suppliers will have to be sought.

(vi) *Can a standard product be found which will be usable?*

The field of standards is a fertile one but *suppliers' standards* as well as *national standards* should be considered. Certain manufacturers have standard components which are not considered as standard by the country as a whole. Likewise, what is non-standard in one industry may be standard in another.

(vii) *Is it made on proper tooling considering quantities used?*

Again, market conditions may have changed and demand increased since production started and larger quantities may allow for better and faster methods to be used now than was originally thought economical.

(viii) *Do material, reasonable labour, overheads and profit total its cost?*

This is a question of price analysis, mainly on components from outside suppliers. If, after analysis of the cost of manufacture, the price paid for a component is considered unreasonably high, the supplier should be asked for the reason.

(ix) *Will another dependable supplier provide it for less?*

This question is designed to stimulate competition between suppliers. The emphasis here must be on "dependable", for it is no part of Value Analysis to sacrifice or jeopardise necessary quality.

(x) *Is anyone buying it for less ?*

This question stresses the need of the Value Analysis Section to widen its contacts and its field of information, both within a company and outside it.

effectiveness

The effectiveness of Value Analysis depends on a number of factors; I have isolated six factors which I consider to be very important, and I would like to comment on them in turn.

1. *Specialisation*

A systematic, thorough and detailed investigation cannot be fully effective if it is carried out as a part-time activity by a person who has other pressing responsibilities, and other routine activities to attend to. The techniques of Value Analysis, as outlined in the preceding section, demand uninterrupted concentration, a wide knowledge and diverse contacts both within and outside the company. Experience has also shown that the success of an investigation is proportional to its intensity. Accordingly, Value Analysis needs to be undertaken by specialists as a full-time job to be pursued scrupulously and with the aim of "*equivalent performance at lower cost*" firmly in view.

2. *Accurate Costing*

The more accurate the costing data available the more reliable will be the work of Value Analysis; also, it is unrealistic to attempt to save farthings unless costs can be measured with the same degree of accuracy.

Thus, the very first task to be undertaken in the Value Analysis of a product is the compiling of what might be termed an "irrefutable cost" for each and every component. This has a double advantage:

1. it ensures that the cost figures used are up-to-date and correct ; and

2. it makes the value analyst scrutinise every item of cost so that any item which appears to him, from his experience, to be excessive, can be marked down for further investigation.

3. *Team Work*

This is a very important factor indeed. The maximum flow of ideas and their acceptance depend on wholehearted co-operation by everybody in seeing the project through. The right climate for the acceptability of this activity must be created by a formal recognition that all the relevant departments are really participating in it and contributing to the project.

In the Author's factory an attempt has been made to achieve this by forming a Value Analysis team.

The team, which meets weekly at a regular time for a regular period is headed by its *Value Analyst* — as team secretary, and includes the *Materials Officer* (as a permanent member representing the buying function and outside suppliers) ; *Draughtsman* (directly concerned with the product being examined); *Assembly Shop Foreman* (similarly concerned); and the *Process Planning Engineer.*

The team is fully responsible for deciding whether to follow up or reject the suggestions which it may generate or receive from other sources. This team responsibility, however, in no way overrides the individual executive responsibility of its members, and does not infringe in any way on the responsibilities of other organisational groups.

Groups not represented on the team — such as Development Laboratories, Work Study and so on — would be contacted by the team's secretary, and other members can be co-opted as required.

Team meetings are conducted briskly and do not attempt to be exhaustive. The main purpose is to stimulate ideas which can be investigated in more detail by the secretary after the meeting.

4. *The choice of the right man as Value Analyst*

While ingenuity and experience are highly desirable, determination and tact are obviously essential. A value analyst must be, above all, diplomatic, remembering that in every project the prior decisions and judgments of other people will be trodden on.

5. *Intensity*

Enthusiasm and interest are hard to maintain for a great length of time. It is therefore desirable for each project to be conducted quickly and intensively — a suggested period is two months.

6. *Management Support*

Finally, to be effective, Value Analysis must have wholehearted management support. It must be generally known that the manager is interested in this activity and keen to get results from it. The manager might take the chair at follow-up meetings to discuss the report, thus lending his weight to any decisions taken on the suggestions.

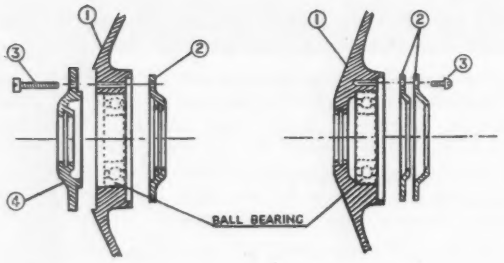
services provided by a Value Analysis section

In the pursuit of their aim, Value Analysis specialists can provide a variety of services to different groups within and outside the company. These services are described briefly below. All or some of the services can be provided, depending on the needs of the company and the ability and size of the section. It is worth noting that *all* the following services are being provided by the Value Analysis Sections of General Electric and the U.S. Navy.

1. *Analysis of Existing Products*

The most usual activity of a Value Analysis Section is the analysis of any existing products that may be submitted to it by the management. Factors affecting the choice of product are important, and are discussed later in this Paper.

A good example of a saving on an existing product, a ceiling fan, is illustrated in Fig. 2. In the original design, the ball bearing in the bearing bracket was



OLD DESIGN

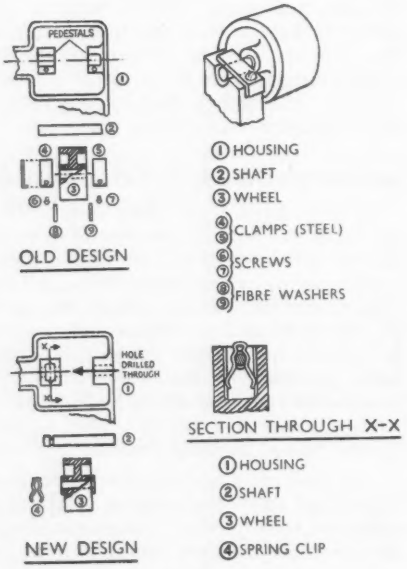
① BEARING BRACKET
② BOTTOM JOURNAL CLAMP (CASTING)
③ SCREW (THREE)
④ TOP JOURNAL CLAMP (CASTING)

NEW DESIGN

① BEARING BRACKET
② BOTTOM JOURNAL CLAMP (TWO PRESSINGS)
③ SCREW (THREE)

BEARING BRACKET JOURNAL CLAMP

Fig. 2.



OLD DESIGN

① HOUSING
② SHAFT
③ WHEEL
④ ⑤ CLAMPS (STEEL)
⑥ ⑦ SCREWS
⑧ ⑨ FIBRE WASHERS

NEW DESIGN

SECTION THROUGH X-X

① HOUSING
② SHAFT
③ WHEEL
④ SPRING CLIP

WHEEL MOUNTING

Fig. 3.

held in place by two cast-iron journal clamps and three screws which passed through clearance holes in the top clamp and the bracket to engage in three tapped holes in the bottom clamp.

In the suggested design, the top journal clamp was eliminated by making it integral with the bracket. Since the bottom clamp only took a light axial load, it was replaced by two pressings secured by three smaller screws running into tapped holes in the bracket and these, being on the inside, could be zinc plated instead of chromium plated.

While the material and machining costs of the new bracket were slightly increased, the elimination of one clamp and the replacement of the other by two simple pressings requiring no machining additional to the press operations, resulted in an overall material saving of 3¼d. per assembly and an overall saving in machining costs of 2s 6d. per assembly. The total saving was thus 2s. 9¼d. per assembled bracket, or £3,300 per annum.

2. *Analysis of New Products*

Probably the most logical time at which to apply Value Analysis is when a new product has reached the prototype stage, but before any tools and special equipment have been ordered. In analysing new products the Section works closely with the design engineers and draughtsmen concerned, in an effort to generate and evaluate suggestions for alternative means of performing the desired function. The distinction between the analysis of existing products and the analysis of new products may seem artificial; the same methods are used for both. Nevertheless, the distinction is made because each presents slightly different problems. In the case of an existing product, accurate information is available about its cost, output rate, production methods, etc., and the task of analysis is thereby made easier. In the case of a new product, however, all such information is based on estimates and the risk of error is increased. Also, the operating groups may be less receptive of suggestions which may delay the start of production or tend to reduce unnecessary factors of safety. For these reasons, the analysis of new products is sometimes carried out too infrequently, although one British motor car manufacturer, I am happy to say, concentrates his Value Analysis effort particularly in this field.

By way of illustration, the analysis of a vacuum cleaner in the prototype stage resulted in a number of good suggestions which it was possible to incorporate only because the very expensive tools and dies had not yet been made. One of these suggestions concerned the mounting of the cleaner's wheels, as shown in Fig. 3. The bakelite wheels were mounted on plain shafts. The ends of each shaft rested in slots cast in the "pedestals" which formed part of the die-cast wheel housing, and were secured in these slots by two pressed steel clamps and two small screws. Two fibre washers acted as spacers between the wheel and the pedestals.

In the new design, the number of components was reduced from nine to four. The clamps and screws were replaced by a wire spring clip which fitted into the slot cast in one of the pedestals, as shown. The

shaft was the same as before but had a small groove machined near one end. The two fibre washers were eliminated by making the hub of the wheel correspondingly wider than the tread. A hole had to be drilled through the two pedestals from the outside of the housing to accommodate the shaft.

The assembly procedure consisted of holding the wheel between the pedestals while the shaft was pushed through the hole in the side of the housing. The shaft was then secured by pressing the spring clip into the groove on the shaft through the slot in the pedestal. The clip fitted tightly into the slot, thus ensuring that the shaft could neither rotate nor move in an axial direction.

The new design resulted in a saving of 3½d. per pair of wheels in assembly cost (75%) and 1d. per pair in material cost. The extra machining cost (drilling) amounted to ¼d. per pair. The overall saving was thus 4¼d. per pair of wheels, or £260 per annum.

3. *Advisory Service to Designers*

In addition to the above two activities, the Section can provide a continuous service, available on request, to advise designers and draughtsmen which of a number of functionally acceptable designs is the cheapest. General information about the effect on costs of unduly fine tolerances or small radii at corners, or about the economics of various production methods, can also be included in this service.

4. *Advisory Service to Buyers*

(a) In the main this consists of picking out purchased items which seem to cost too much, as, for example, a stamped washer. Its price of 8½d. seemed excessive and it transpired that when the washer was first bought some four years ago, only one firm tendered a quotation out of the several approached, and so perforce got the order. The Value Analyst advised the buyer to get further quotations, with startling results. The original supplier immediately requoted a price of 4¼d. each, explaining that "the cost of tools had now been recovered". Another supplier (from Oldbury, where they obviously work rather harder), quoted a price of 1¼d. each, and is now supplying these washers at a standard of quality equal to the original. The saving of 7¼d. per washer (85%) needs no further emphasis.

(b) In a more advanced form the advisory service to buyers can take the form of price analysis. Its purpose is to provide the buyers with information which will help them in negotiating prices with a supplier that will be as close as possible to production costs, while allowing a reasonable profit for the supplier.

5. *Advisory Service to Suppliers*

A Value Analysis Section which maintains extensive contacts with suppliers and encourages their interest and suggestions can, in return, help the suppliers to reduce their manufacturing costs by visiting their factories and making a study of their production methods. This service is, of course, guided by self-interest. Nevertheless, it can be of real worth to both parties, resulting in lower costs to the company and better business opportunities to the suppliers, particularly as the benefits of any lower production costs can be shared by them with their other customers.

6. *Training in Value Analysis Methods*

Value Analysis methods are easy to describe and the results of investigations can be demonstrated very effectively. The Section is in an excellent position, therefore, to conduct training activities designed to increase the cost consciousness of the company's staff. These activities can take the form of periodic lectures to designers, production engineers, supervisors, buyers and others. More ambitious training courses can also be provided on a part-time or full-time basis, depending on the resources of the Section and management support.

The savings which result from effective training cannot be measured, but their potential is great indeed. A cost-conscious staff is a great asset to any company and all methods that seem likely to increase this cost-consciousness are well worth trying.

A by-product of Value Analysis training schemes is that they help more than anything else to secure the acceptance of a new Value Analysis Section by the rest of the company staff.

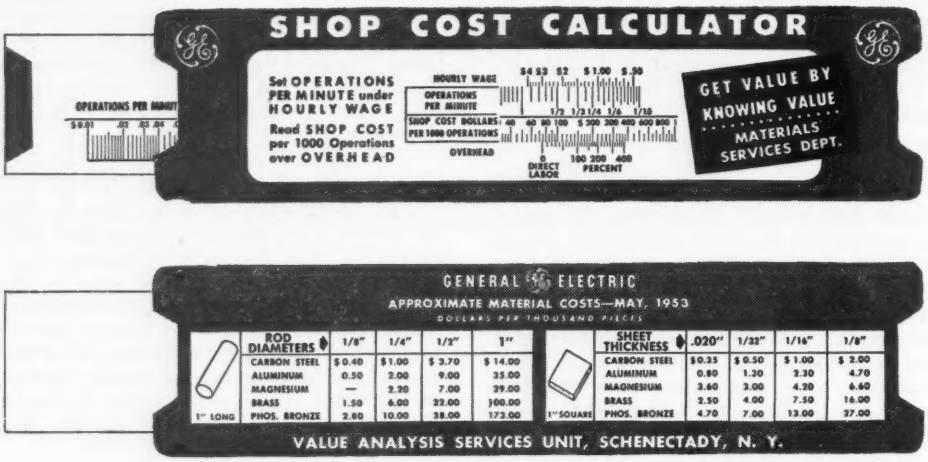
7. *Information and Publicity Service*

A Value Analysis Section can also foster and reinforce a cost-conscious attitude in the company by issuing pamphlets or news sheets containing specific information on new materials, processes and tools; in fact, any details which might help designers, buyers and others to reduce the costs of activities under their control. In addition, considerable publicity can be given to cost-saving ideas by means of posters and circulars.

The General Electric Company of America circulate the "Value News", which is a one-sheet publication issued weekly to as many people as possible — currently 3,500. Its aim is to stimulate "value thinking". Each week a different specific example of how greater value can be obtained is described in cartoon form, which is not only eye-catching but is designed for "ten-second reading". The idea is that the time which elapses in-between picking the Value News out of an in-tray and filing it in the waste-paper basket, is sufficient for the recipient to absorb the message!

There is also *"New Materials News"*. This is a supplementary publication consisting of a number of typewritten sheets which present some 20 or 30 short summaries of recent developments in all types of materials, processes and tools, and where these may be obtained. The pamphlet is issued monthly to about 2,000 people.

In order to promote cost-consciousness the G.E. Value Analysis Section has developed and distributed a simple cardboard slide rule, named a *"Shop Cost Calculator"* (Fig. 4). The slide rule enables the rapid



ROD DIAMETERS	1/8"	1/4"	1/2"	1"
CARBON STEEL	$ 0.40	$ 1.00	$ 3.70	$ 14.00
ALUMINUM	0.50	2.00	9.00	35.00
MAGNESIUM	—	2.20	7.00	29.00
BRASS	1.50	6.00	23.00	100.00
PHOS. BRONZE	2.80	10.00	38.00	173.00

SHEET THICKNESS	.020"	1/32"	1/16"	1/8"
CARBON STEEL	$ 0.35	$ 0.50	$ 1.00	$ 2.00
ALUMINUM	0.80	1.20	2.30	4.70
MAGNESIUM	2.60	3.00	4.20	6.60
BRASS	2.50	4.00	7.50	16.00
PHOS. BRONZE	4.70	7.00	13.00	27.00

Fig. 4.

calculation of the shop cost (material, labour and overheads) at various wage and work rates.

On the reverse side of the rule is printed a table showing the approximate cost per thousand pieces of five common materials (carbon steel, aluminium, magnesium, brass and phosphor bronze) in rods of standard diameters and sheets of standard thicknesses. This information quickly gets out of date, of course, but the slide rule is merely a gimmick and if it drives home the idea of cost-consciousness, then its purpose has been achieved.

Publicity which is designed to stimulate suggestions from suppliers, can take the form of displays of the component parts of the company's products, together with sub-assemblies illustrating their functions, situated in the reception room of the Buying Office, under a prominent title-board with the legend, for example, as shown in Fig. 5 — "What are your suggestions ?" 4. I believe such displays have produced some excellent results in a number of American firms.

organisation of Value Analysis

(1) organisation of a Value Analysis Section

The size of a Value Analysis Section depends on the size of the company and on the monetary return on the investment made in its activities.

Assuming that the Value Analysis Section consists of several persons, it should be organised in such a way that it is best equipped to carry out the services listed above. Ideally, then, it should include people with design experience, others with production engineering background, buying experience, and cost accounting knowledge. The more diverse the combined experience of the Section, the better.

(2) the place of Value Analysis in the company

There is no hard and fast rule about the position of Value Analysis in an organisation. Practice in this respect varies considerably from firm to firm.

While those companies which have centralised design or other staff functions may successfully employ Value Analysis as a centralised activity, it is concluded from the experience of General Electric and the U.S. Navy that companies which are made up of decentralised largely autonomous productive units, would do well to limit the activities of a central Value Analysis Section to training and information services, *while the actual analysis work on the products should be carried out by small "field-units" responsible directly to the managers in whose factories they operate.* This arrangement tends to mitigate a great deal of the resistance which the "outsiders" from a central staff seem to meet when working on projects within the autonomous factories.

It is necessary, however, that wherever the Value Analysis Section is located, it should be clearly recognised as a *service* function and used as such. It should also operate and report at a high enough level to ensure that action will be taken on the suggestions that are put forward. Finally, it should be so placed that it has easy access to the design, manufacturing and purchasing groups, and it should have the wholehearted support of the management in those areas in which it operates.

operational problems

Value Analysis, like any staff function, is subject to a number of operational problems. The two main problems are :-

(i) introducing Value Analysis and getting it accepted; and

(ii) overcoming conservative attitudes which exist in any company.

(i) introduction

This may be met with suspicion in certain departments who see in this activity a challenge to their ability to get a cheap product from the beginning.

This must be handled carefully and tactfully and Value Analysis must be "sold" rather than imposed. Certainly the use of the "big stick" is fatal — it may get apparent results and lip-service, but it will fail to get the co-operation from which good ideas are born.

A good way of overcoming this difficulty is to tell the department heads all about it — what it entails and the ideas behind it. Their co-operation must be sought in setting up the Value Analysis team, thereby ensuring that each department is represented in the team and has a function in producing the final report. thus identifying themselves with the suggestions.

It is also a good idea to explain Value Analysis to shop floor representatives and to encourage them to participate via any suggestion scheme that a company may run.

(ii) conservative attitudes and resistance to change

In every company and many departments of each company, there are people who, either through temperament or overwork, are hostile to new ideas — nowhere more so than on the shop floor.

Let us ponder, for a moment, on how many times we have heard a good idea liquidated or seriously crippled by any one of the sort of dogmatic comments illustrated in Fig. 6 4.

If anyone has not heard these before, then he is either very fortunate or deaf.

By way of illustration I would like to quote, from a nameless American source, an extreme example of an actual case. It demonstrates, I feel, the triumph in adversity of the Value Analysis approach:

> "The manager of the factory sent in a little pin about $\frac{3}{8}$ in. long and the thickness of a pencil lead. He said 'We use 50,000,000 of these a year; they cost about one-third of a cent each. Is there anything you can do about it?' We asked for a meeting to be set up with the engineer in charge of it, the vendor who supplied it, his superintendent, our buyer and ourselves. It was arranged. The engineer opened the meeting with the words: 'I don't know the purpose of this meeting. We have to have all the requirements of the specification on this pin and the price that we are paying is a good price, but here we are.'
>
> "This was not a very good start but in this sort of work we have learnt not to be discouraged. So we attempted to explain courteously that there were probably things that could be done with the specification — things that were not paying off. He said immediately that he knew there were not. We then asked the vendor to list the processes he used in making the part. He

Fig. 5.

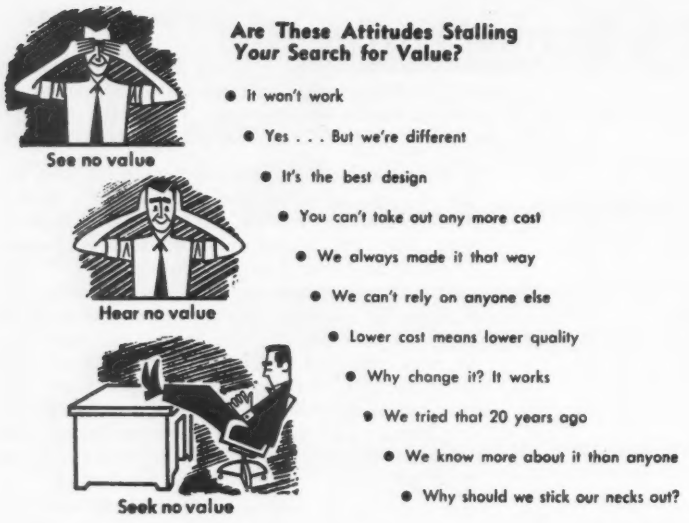

Are These Attitudes Stalling
Your Search for Value?
See no value
Hear no value
Seek no value
• It won't work
• Yes . . . But we're different
• It's the best design
• You can't take out any more cost
• We always made it that way
• We can't rely on anyone else
• Lower cost means lower quality
• Why change it? It works
• We tried that 20 years ago
• We know more about it than anyone
• Why should we stick our necks out?

Fig. 6.

named 13 different steps. We started studying them specifically, and we found that he started with a material that was so large that he had to use three centreless grinding operations to get it down to size. He could just as well start with a smaller material and bring it down in one step. We found that he set up his factory drawings on one key tolerance at half our tolerance, just so that he would never have any trouble. He was throwing away everything that came between his tolerance and ours which would be perfectly usable to us and, of course, charging this to the job — throwing good pins away at our expense.

"We found quite a number of other things. The result was that this vendor requoted the price a week later; from $3.65 a 1,000 to $1.90 a 1,000 — for the identical part. That reduction made a difference of $112,000 per year in our purchase cost."

This is an extreme case but it shows what can be done when people are not even aware that there is a saving to be made.

In general, gentle but firm handling and tactful persistence overcome these attitudes. In more severe cases the suggestion should go into the final report and the decision be left with the executive groups.

scope

At this stage, some of you may be saying to yourselves :-

"This is all very well for the mass-producer making 50,000,000 pins a year — but how can Value Analysis possibly apply to a jobbing factory or to small batch production ?"

To some extent your doubt is valid — it is easy to save farthings, and one farthing saved on a component made at the rate of a million per year realises something over £1,000.

But I would ask you to remember that even a ship, which is the classic example of jobbing production, presents mass-production opportunities in regard to some of the components and materials used in its manufacture; as for example, screws and rivets, welding rods, piping and cable, and so on.

Also, in general, unit savings increase with the size of the components, and this, to a little extent, tends to offset the disadvantage of smaller output quantities of products such as large generators, turbines or heavy-duty switchgear.

In a similar way, the effectiveness of Value Analysis increases with the variety of products or parts made in a factory. The greater the range of items with which the design staff is concerned, the less attention they can normally pay to each item, and the greater the likelihood of alternative materials and designs being overlooked by them. This is particularly true at the present time while the national shortage of engineers and draughtsmen persists.

It follows from these considerations that Value Analysis is more suited, though not necessarily confined, to an industry producing multi-component products, such as the engineering industry, than to process industries such as the chemical and textile industries.

justification

Having considered what Value Analysis is, and how it functions, the questions may well be asked : "What justification is there for it ?" and "Why should we introduce yet another speciality, in this age of specialist functions ?".

Well, of course, there is, in theory, no real justification for Value Analysis at all. But in practice it is often very effective indeed. The main reasons why this is so were contained in the statement I quoted at the beginning of this Paper, namely :-

(i) personal limitations;
(ii) patterns and habits of thought;

(iii) difficulties in promptly disseminating ideas (and also information about new developments): and
(iv) because today's thinking is based on yesterday's knowledge.

There are, in addition, certain other factors, and I would like to stress three of them :-

(i) designers usually have to work to a target date, and so simply lack the time to explore all possible alternatives;
(ii) once the product is in production, new conditions may develop, new materials may become available, new techniques may be evolved. But no one with routine responsibilities may have the time for periodic re-appraisals of the product and its constituent parts;
(iii) genuine pride in the product may result in the use of the *best* material and method and not the merely *good enough*.

Value Analysis is not new in its aims, which, after all, are the underlying aims of every competitive business. What is new is its approach which consists of a specialised, carefully planned and intensive attack on product costs, but *not* at the expense of quality. The measure of its success is shown in its results; Value Analysis more than pays for itself, and its results, by their very nature, show whether it is paying for itself or not.

conclusion

I would like to conclude with this partial quotation from the poem by Samuel Walter Foss, written in 1895, and adapted elsewhere 6.

PATH OF THE CALF

"On day through the primeval wood
A calf walked home as good calves should:
But made a trail all bent askew,
A crooked trail as all calves do.
Since then three hundred years have fled,
And I infer the calf is dead.
But still he left behind his trail,
And thereby hangs my moral tale.
The trail was taken up next day
By a lone dog that passed that way:
And then a wise bellwether sheep,
Pursued the trail o'er vale and steep,
And drew the flock behind him, too,
As good bellwethers always do.
And from that day o'er hill and glade,
Through those old woods a path was made.
The years passed on in swiftness fleet,
The road became a village street;
And thus, before men were aware,
A city's crowded thoroughfare.
And soon the central street was this
Of a renowned metropolis;
And men two centuries and a half
Trod in the footsteps of that calf.
Each day a hundred thousand rout
Followéd this calf about
And o'er his crooked journey went
The traffic of a continent,
A hundred thousand men were led
By one calf near three centuries dead.
They followed still his crooked way,
And lost one hundred years a day:
For thus such reverence is lent
To well established precedent."

acknowledgments

I am greatly indebted to the following organisations which have provided me with information and illustrations for a report prepared for the Department of Engineering Production, University of Birmingham, on which this Paper is based :

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The A.C. Gilbert Company, U.S.A.;
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and to
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I would also like to express my sincere thanks to the University of Birmingham for permission to publish this Paper and, above all, to The General Electric Company Ltd. (Witton), for sponsoring my work in the Department of Engineering Production.

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cemented carbide tools —

their application for increased productivity in heavy and general engineering

A Thesis by D. C. Rodgers, A.M.I.Prod.E.,

Assistant Works Superintendent, Hadfields Ltd., Sheffield.

DURING the past thirty years, an elaborate and comprehensive technique for the machining of engineering materials, using carbide-tipped tools, has grown up from simple beginnings. Development at first proceeded slowly, because of opposition from the well-established high speed tool operators, but was later accelerated as it came to be appreciated that the newer developments in engineering materials and the need for higher cutting speeds had outstripped the available cutting tools.

With progress, and the acquisition of a better knowledge of cutting tools gained generally through experiment and research, the procedure of using carbide-tipped tools has become increasingly complex and searching, and has been, more or less, an established form for many problems for a number of years. Further developments are now being made in new cutting compounds to meet the requirements of the newer materials and the still higher cutting speeds that are being sought.

As will readily be appreciated, the information on cutting tools, both high speed and carbide-tipped, is voluminous, since it has received the attention of so many eminent engineers. Such information is usually found in manufacturers' catalogues and technical magazines.

This has prompted the Author to write this paper on the use of carbide-tipped tools in the general engineering machine shop as a means of increased productivity, and it is hoped that sufficient information has been provided to enable the layman to agree that the statement is justified.

problems encountered in the introduction of carbide tools

advantages for high and low speed machining

Carbide tools have solved an increasing number of machining problems during the past few years, especially in the type of machine shop where a large range of machining at high and low speeds is necessary due to the wide variety of products called for by industry, ranging from items of small diameter and a few pounds weight, to large forgings and castings weighing from twenty to thirty tons. The main advantage of carbide tools over conventional tools is that the free-cutting steels normally encountered can be machined more rapidly since faster speeds and feeds can be employed, while the harder alloy steels can be machined at lower speeds than it was previously thought possible to attempt with safety.

With regard to cemented carbides, the opinion in the past that cutting speeds below 100 feet per minute and over 1,000 feet per minute were not possible, is no longer true. It has been found that the principal reason for carbide tool failure in the high speed range was primarily due to the heat generated during the machining operation, which caused the carbides with their high red hardness to fail at the cutting edge. In the lower speed range, however, it was found that the cutting forces increased as the speed was reduced (i.e. the forces varied inversely as the speed) thus causing a building up of metal at the cutting edge, which fused to the tool material. This built-up material left the tool intermittently and tended to break off fragments of the cutting edge, thus bringing about early failure of the tool.

At present, as a result of improved tool design and better grades of carbide, speeds as low as 10 ft. per minute have been successfully used for machining, such a speed being frequently required in the heavy machine shop. The secret of low speed machining would appear to be correct tool design and the selection of the appropriate grade of carbide, coupled with the lapping of the cutting edges.

Whilst the high speed range of cemented carbide tools is generally still under 1,000 ft. per minute, speeds over this figure are now being successfully attained by the use of ceramic oxides, but these higher speeds have been achieved mostly in finishing

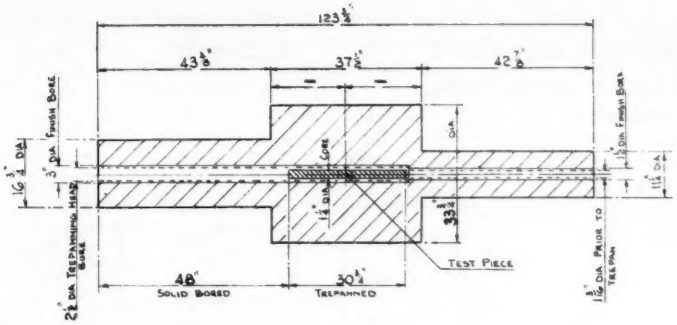


Fig. 1. Rotor.

operations. Since new problems are always arising, it would be unwise to suggest that the stage has been reached when no further development will take place to produce still higher speeds to enable machining times to be reduced still further.

The following are examples of low speed machining:

(*a*)	Product	: Back up roll.
	Type of steel	: carbon-molybdenum-vanadium 112 tons/sq. in. tensile.
	Condition	: Heat treated to 78 scleroscope (575 V.D.P.H.).
	Operation	: Machining the barrel or body.
	Diameter of barrel	: 33.5 in.
	Length of barrel	: 87 in.
	Speed used	: 28.3 ft. per minute.
	Feed used	: 0.023 in. per rev.
	Depth of cut	: 0.125 in.
	Time taken	: 18.9 hours.

Cutting was successfully performed by a "Wimet" Grade XX7 carbide tool[1] which did not need regrinding. This was a standard bar turning tool, except that it was ground with a 3° side primary rake on the tip, a 5° secondary rake on the shank and with a $\frac{1}{32}$ in. radius on the point of the tip. The tool had no top rake, i.e. the tip was ground flat or neutral and, of course, the cutting edge was finely lapped.

(*b*)	Product	: steel ram.
	Type of steel	: nickel-chrome-molybdenum.
	Condition	: Heat treated to a hardness of 500 Brinell.
	Operation	: Finish machining of bore of ram.
	Diameter of bore	: 2.2 in. $\pm$.0025 in.
	Length of bore	: 32 in.
	Speed used	: 57.2 ft. per minute.
	Feed used	: 0.25 in. per minute.

The bore had previously been roughed out before treatment, leaving an allowance of $\frac{1}{4}$ in. for finishing. The tool used for finishing the bore was a carbide floating cutter fitted with "Wimet" Grade H tips. The finish obtained was quite smooth and within the tolerance specified.

(*c*) For research purposes it had been decided that a test piece should be procured from the centre of a carbon-molybdenum steel rotor, the tensile strength being 45 tons/sq. in.

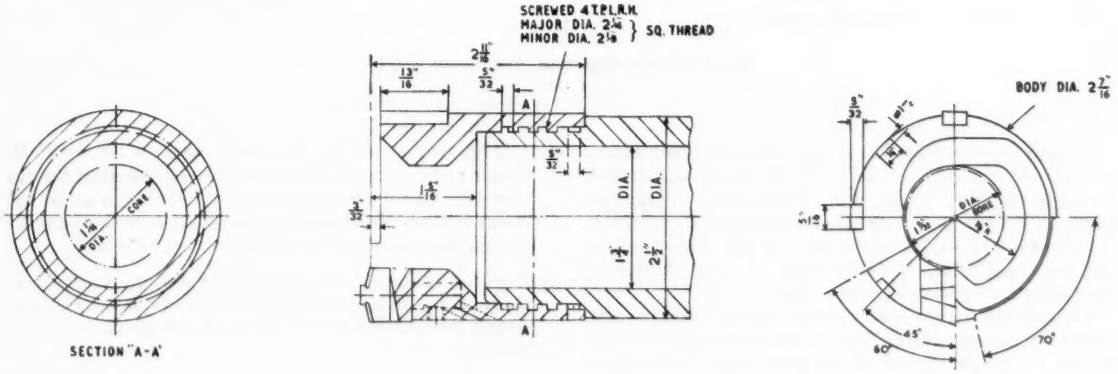


Fig. 2. Trepanning head (Scale: 1/1).

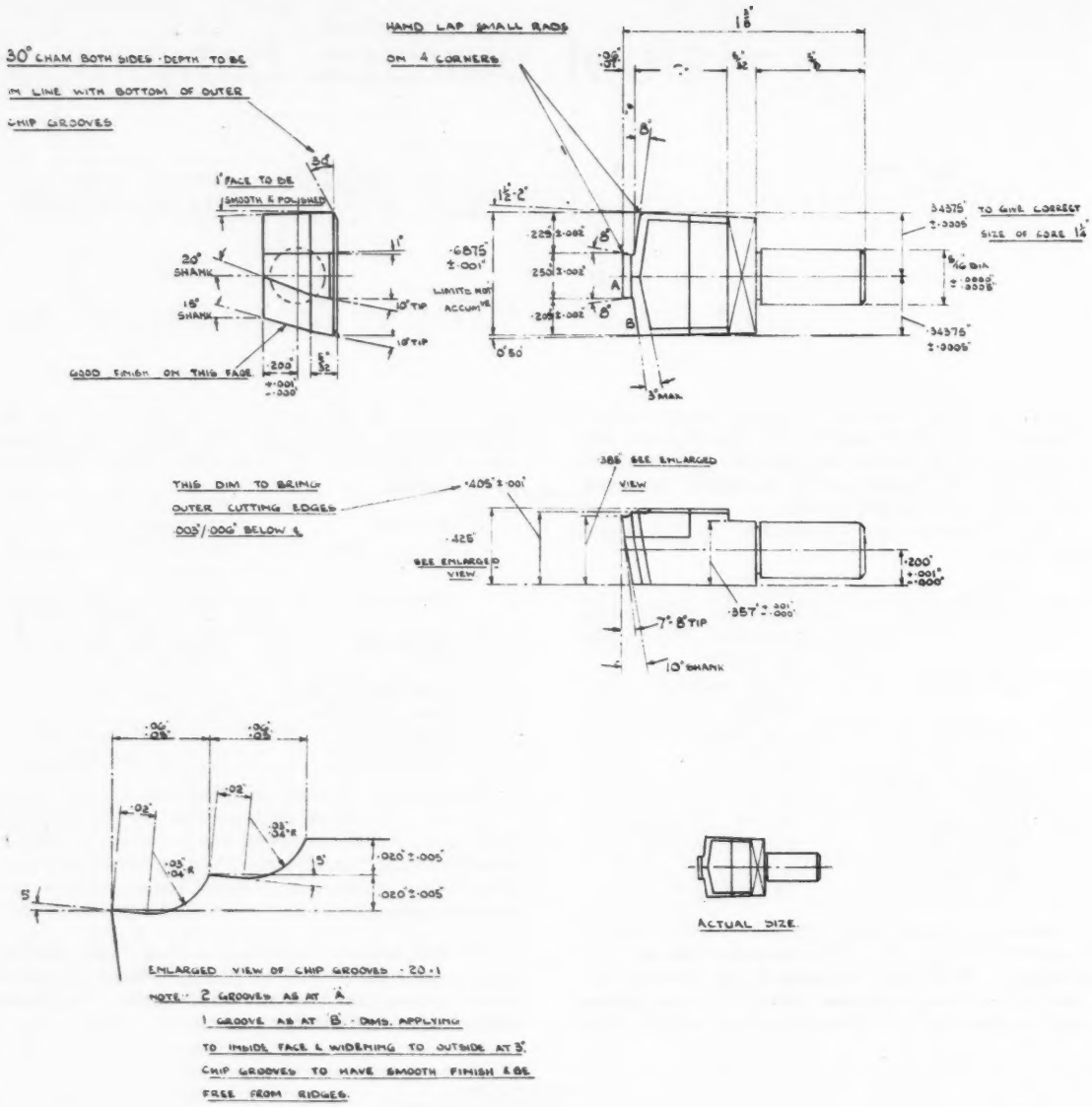


Fig. 3. Trepanning head tool (Scale: 2/1).

As will be seen from Fig. 1 the rotor had two bores, one of which was 3 in. dia., 78¾ in. long, and ended in a second bore 1½ in. dia., 45 in. long. The test piece called for was to be taken from a position in the 3 in. bore 62⅛ in. from the end of the rotor and its size was 1¼ in. dia. by 14 in. long. It was, therefore, necessary to trepan this test piece.

Consideration was given to the idea of using a high speed trepanning cutter, but it was eventually decided to use a carbide cutter[1] of the type which previously proved successful for trepanning gun barrels, oil pipes, etc., at high speed.

The two bores in the rotor had to be perfectly smooth and concentric, hence it was essential for the carrying out of the trepanning operation to make the bores smaller in diameter than called for and finally to machine these to the finished sizes required.

Much thought was given to the design of a suitable trepanning cutter, and details of the one it was thought would be satisfactory for the work are given in Figs. 2 and 3.

The trepanning tool cuts an outside diameter of 2½ in. and produces a core 1¼ in. dia. The test

piece was carried out in the following manner: a $1\frac{3}{16}$ in. dia. hole, 45 in. in length was first bored in one end of the rotor; thus an allowance of $\frac{5}{16}$ in. was left to produce the finished bore of $1\frac{1}{2}$ in. dia. A $2\frac{1}{2}$ in. dia. hole was then bored from the opposite end of the rotor for a length of 48 in. making certain that the $2\frac{1}{2}$ in. dia. trepanning cutter was a good fit in the bore for this length. Trepanning was started from this point in order that the test piece to be produced would be $30\frac{3}{4}$ in. long (i.e. the length of the 3 in. finished bore—$78\frac{3}{4}$ in. less the length of the $2\frac{1}{2}$ in. bore, 48 in.) and would, of course, detach itself from the rotor at the intersection of the two bores. The two bores then required finish boring to the diameters called for, i.e. 3 in. and $1\frac{1}{2}$ in. respectively.

Cutting commenced and the centre portion of the tool bit immediately broke off. A replacement cutter was fitted and trepanning recommenced. Again the centre portion of the tool bit broke off. After several attempts at cutting, which only succeeded in breaking off the centre portion each time, it was decided that the design of the tool bit being used was not the correct one for the job in hand; therefore, the tool bit was re-designed and the modified cutter re-fitted. This proved successful and the test piece was subsequently procured from the rotor, after which it was sawn off to the required length. The two bores in the rotor were then machined to the finished diameters of 3 in. and $1\frac{1}{2}$ in. respectively. The principal dimensions of the modified trepanning tool are shown in Fig. 4, and details of the operation are given below:

Diameter of hole	:	$2\frac{1}{2}$ in.
Speed used	:	26 ft. per minute.
Feed used	:	.093 in. per minute.
Length of test piece	:	$30\frac{3}{4}$ in.
Time taken	:	$5\frac{1}{2}$ hours.

This design of tool has since been used to provide, from several types of rotors, test pieces as low as $\frac{5}{8}$ in. dia. ($1\frac{3}{8}$ in. over cutting edges of tool).

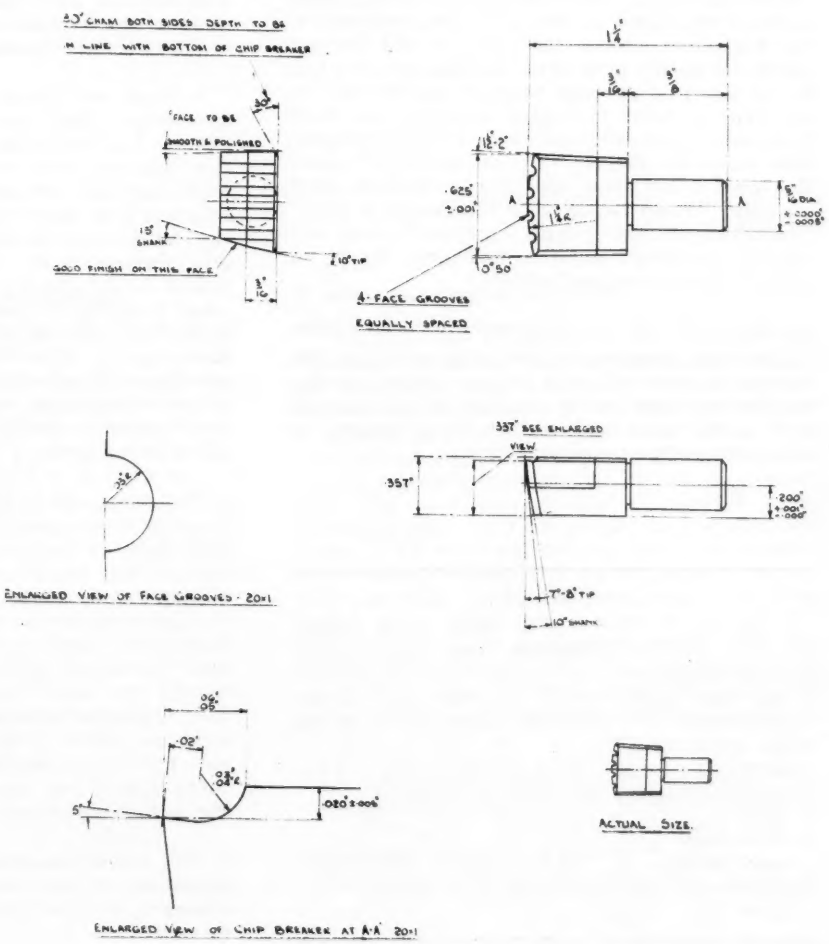

GOOD FINISH ON THIS FACE
4 FACE GROOVES EQUALLY SPACED
ENLARGED VIEW OF FACE GROOVES · 20:1
SEE ENLARGED VIEW
ACTUAL SIZE.
ENLARGED VIEW OF CHIP BREAKER AT A-A 20:1

Fig. 4.
Modified trepanning head tool (Scale: 2/1).

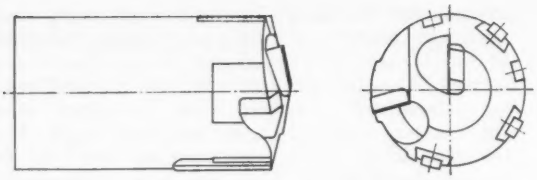


Fig. 5. Carbide deep boring head.

Let us now compare the results when using carbide tools and high speed tools. The workpiece used in the tests was a high carbon-chromium steel roll, 45/50 tons tensile, in the annealed condition, and the operation carried out was the boring of a 2½ in. dia. hole through its centre.

(*a*) *carbide tool used on a special high speed boring machine*

A high speed boring machine was available, this having been recently installed for the purpose of boring gun barrels. It has also been adapted for commercial work. Since the success of high speed boring is dependent on the correct heat treatment of the workpieces, and as the carbides used for high speeds are mainly those of the finishing grades which do not stand up to rough usage, it was felt that the best type of cutter to employ would be one which had a solid type boring head with a rough grade carbide centre tip, namely "Cutanit Grade R"[2] where the speed is not great, and with a finishing grade wing tip, "Wimet Grade XX7"[1] illustrated in Fig. 5. The boring operation, using this type of cutter, was entirely successful, and the machining details are given in the comparison Table I.

(*b*) *high speed cutter on conventional type boring machine*

The same operation, i.e. the boring of a 2½ in. dia. hole in the steel roll, as in (*a*) was carried out on a conventional type boring machine using a standard high speed cutter and the machining figures are also given in the comparison Table I.

TABLE I.

	Operation	*Speed used*	*Feed used*	*Time taken*
Carbide deep boring tool high speed borer	Boring	195 ft./m.	.907 in./m.	2 hrs. 18 min.
High speed steel cutter Conventional type borer	2½ in. dia. hole	26 ft./m.	.15 in./m.	14 hrs.
Carbide/high speed cutter Conventional type borer	10 ft. 6 in. long	45.5 ft./m.	.35 in./m.	6 hrs.

(*c*) *carbide/high speed cutter on conventional type boring machine*

In order to cut down the length of time taken to carry out the boring operation on the conventional type boring machine, generally available in most heavy machine shops, the Author designed a special carbide/high speed cutter. This will, no doubt, be of some interest and, therefore, its manufacture will be fully described as follows:

The cutter has a high speed centre portion, hardened to 820 V.D.P.H. approximately, since, as in the case of a twist drill, the centre is travelling fairly slowly and could be said to be practically stationary, whilst the serrated or stepped cutting edges of the tool are made up of two carbide tips in order to accommodate the fast speed of the periphery of the cutter.

Many difficulties presented themselves during development and successful manufacture of this cutter, the principal one being that the tips became detached from the cutter during the boring operation. This difficulty was eventually overcome in a simple manner and is explained later, but first the making of the cutter will be described:

A blank was forged, annealed and milled to the appropriate sizes, including the serrated cutting edges. The machining of the seatings for the tips then followed, after which the cutter was ready for hardening and tempering. When the cutter was returned from heat treatment and oil quenched, the tip seatings were cleaned with carbon tetrachloride and abrasive cloth. The carbide tips were next brazed to the cutter, using silver solder, care being taken to protect the point of the cutter with asbestos to prevent softening by the torch. The cutter was finally ground to the correct size in a tool and cutter grinding machine, while the steps of the cutting edges of the carbide tips, which were a roughing grade, i.e. "Cutanit Grade R", were ground with the aid of a diamond wheel.

The chief cause of failure of the cutter in its early stages of development, due to the detachment of the tips during boring, was attributed to grease and oil left on the cutter whilst brazing. Investigations showed that all grease and oil was not removed from the cutter by the carbon tetrachloride and abrasive cloth, since some was found clinging to the marks made by the milling cutter in machining the seatings for the tips. Shot-blasting of the cutter was, therefore, resorted to immediately after heat treatment and, of course, prior to brazing the tips. This proved very satisfactory, and the cutter made by this revised method gave very good performances. Details of the carbide/high speed cutter are given in Fig. 6.

This cutter was then used to carry out the same operation on the workpiece as in the previous examples, (*a*) and (*b*), and the figures obtained are given in Table I.

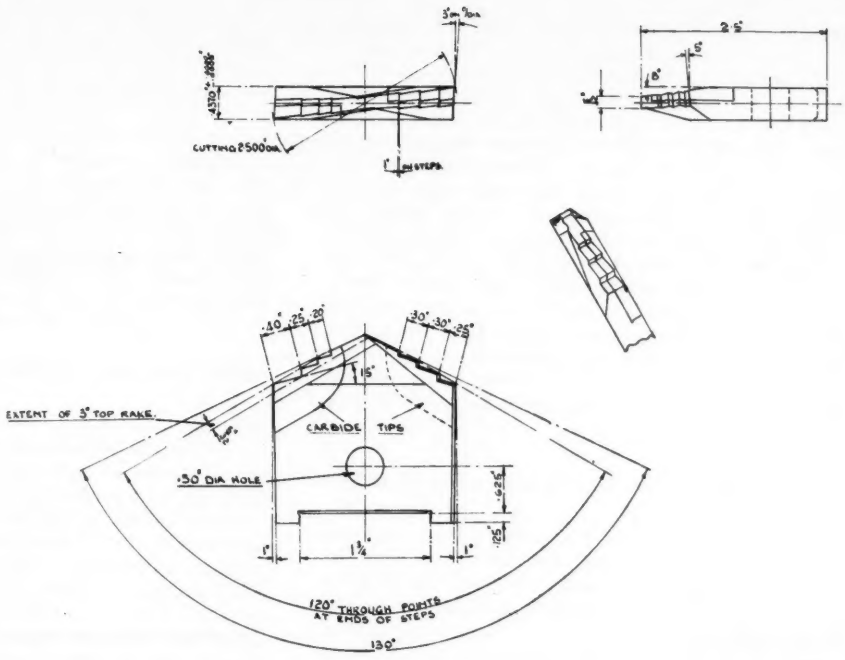


Fig. 6.
Carbide high speed cutter (Scale: full size).

examples of high speed machining

1. machining large hollow forgings 17½ in. dia. by 54 in. long, 45 tons tensile steel

The outside contour of the hollow forging during machining was controlled by means of a former. This operation was performed in two stages, i.e. one roughing cut and one finishing cut. In the first stage, a standard bar turning tool was used to turn the parallel portion of the work piece, and was replaced by a round nose turning tool to form the nose or ogive. The second stage, i.e. the finishing stage, was completed in like manner. However, in order to increase production, a tool was designed to do the work of the two tools previously required, i.e. the whole of the projectile contour, including the nose, was turned using a single tool, although it was still necessary to retain the roughing and finishing cuts. A sketch of this combined standard bar and round nose turning tool is given in Fig. 7, and its performance figures are as follows:

Details	*Stage* 1— *Roughing Cut*	*Stage* 2— *Finishing Cut*
Dia. of workpiece	17½ in.	16¾ in.
Speed used	182 ft. per min.	267.3 ft. per min.
Feed used	.0125 in. per rev.	.0125 in. per rev.
Depth of cut	⅜ in.	⅛ in.

2. milling the drives of steel rolls

This operation is carried out on a 22 in. centre "Craven"[3] tenon and wobbler end milling machine and is accomplished in the following manner: two flats are milled diametrically opposite on the journal of the roll by using a 10 in. dia. carbide face mill and, incidentally, when one flat has been machined the roll is indexed through 180° to mill the opposite flat. The cutter has eight blades fastened by means of wedges and these are ground to negative helix angles of 10°. During the past few years, carbide-tipped milling cutters, with the blades set at negative rake and helix angles for machining steels, have rapidly come to the forefront due to the fact that negative rake gives a stronger cutting edge and enables the cemented carbide tips to withsfand the severe shocks encountered in taking interrupted cuts. A typical example of one of these drives is as follows:

Carbon chromium steel roll	45 tons tensile.	
Diameter of journal	11.938 in.	$\pm$.001 in. .000
Length of flat	13 in.	
Width across flats	8.808 in.	$\pm$.002 in. .000

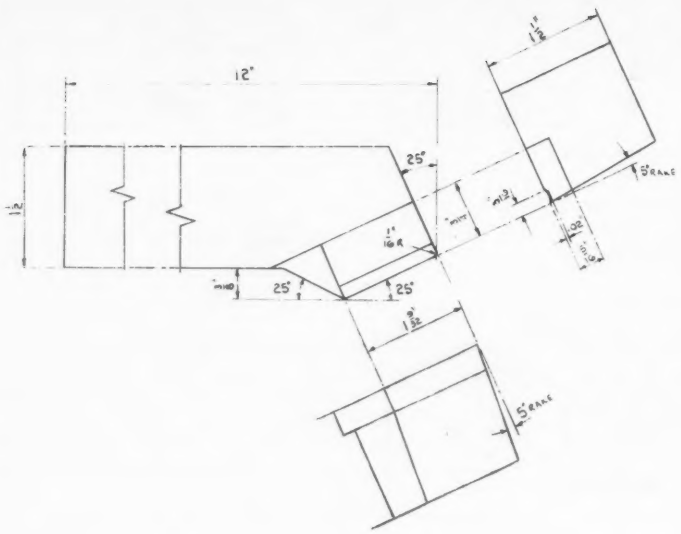


Fig. 7. Carbide roughing tool (Scale: full size).

Machining Figures

Speed in ft. per minute	:	238.27.
Feed	:	1.82 in. per minute.
Depth of cut	:	0.5 in. roughing. 0.065 in. finishing.
Time taken	:	58 mins. approximately.

Therefore, 1.565 in. depth of material is machined from each side and this is obtained by taking three roughing cuts .5 in. deep and one finishing cut .065 in. deep.

3. boring pipe moulds

These are bored on a high speed boring machine with a conventional carbide solid boring tool employing "Wimet Grade X8" as the centre tip and a wing tip of "Wimet Grade XX7". Particulars are as follows:

Steel	:	nickel-chromium-molybdenum 50 tons tensile.
Length of workpiece	:	15 ft.
Dia. of hole to be bored	:	2½ in.
Speed	:	260 ft. per minute.
Feed	:	1.5 in. per minute.
Time taken	:	2 hours.

The few examples mentioned show the advantages of carbide tools for the various types of machining operations which, on account of the nature of the steels involved, come within the low or high speed machining.

Having had the opportunity of designing carbide tools, and the responsibility for innumerable tests, the Author has been able to prove to those responsible for controlling heavy machine shops that these tools provide a vital and economical contribution towards machining the numerous and varied types of forgings and castings now being encountered.

familiarisation of operators

The majority of operators in the general engineering and heavy machine shops are skilled men who have, in the past, re-ground their own high speed tools. On the introduction of carbide tools they proceeded to treat them in the same manner as high speed tools and, consequently, complained that the tips of the tools were cracking, intimating that carbide tools were not so good. This practice of the re-grinding of carbide tools by the operators was difficult to overcome and it became evident that the men would have to be instructed in the application of carbide tools. As a first step, instructions were given for all carbide tools to be returned to a central department for re-grinding. This did not appeal to the men, who regarded it as a slur on their skill. Hence, means of educating them regarding carbide tools had to be evolved and education in this respect is a somewhat slow process. Having regard to this, one well-known firm[1] set up a school where machine shop personnel could learn the intricacies of carbide tools. This school serves an extremely useful purpose, but it does not appear practicable when the number of employees in the machine shops is in the region of several hundreds, as is the case at the Author's works, since too much time would be required to cover all personnel.

To overcome this difficulty, it was decided in the first place to give a series of lectures on carbide tools to the foremen and chargehands of the machine shops, and as a result of these lectures many interesting discussions took place. The shop stewards were then brought into the picture and their co-operation secured. After exercising a great deal of patience the men were won over to the new process. From that time, the belief that carbide tools are the be-all and end-all of cutting tools seems to have become

prevalent. This, however, is not strictly true, since they have their limitations and a field for both carbide and high speed tools still exists, although it would appear that in the future a similar relationship will exist between carbides and ceramic oxides. Most operators today are definitely carbide conscious and, of course, psychology plays a big part in this, since if a new make or grade is introduced for trial purposes and does not meet the requirements of the one already being used successfully, they are not long in acquainting the management in no uncertain terms, for they know their carbides. This shows their great interest and indicates the important part carbides play in present-day production.

provision of adequate service and tool utilisation

Manufacture of tools with carbide tips has been given great prominence in literature published by the various manufacturers of this type of product, and very little remains to be said, except that in large firms it is usual to have a special section of the toolroom or central department available for the purpose of making, re-grinding and maintaining cutting tools. Carbide tips are normally purchased from well-known manufacturers and brazed to 0.5/0.6 per cent. carbon steel shanks made from rolled bar, except in special cases, when they are forged. Great care is needed in brazing to prevent rapid changes in temperature of the hard metal during the operation. All heavy duty tools, i.e. those taking cuts up to one inch deep, are brazed with electrolytic copper, having a melting point in the region of 1,080°C. Clamped tipped tools have been tried, but in rough turning operations, where deep and intermittent cutting takes place, the swarf tends to rip off the clamp; therefore, they are utilised on light machiinng operations. All the harder grades of carbide, when brazed, utilise silver solder as the medium, and in some cases the insertion of steel wire gauze (approximately .005 in. to .010 in. thick) has been introduced, to ensure a sufficient cushion of brazed metal. This tends to absorb some of the stresses set up by the different rates of contraction of the carbide and the shank material during cooling. To-day, brazing is mostly carried out using the high frequency induction method which is very satisfactory when using silver solder (melting point 650°C.) or Sifbronze (melting point 850°C.). When copper is employed as the compound, the higher melting point (1,080°C.) tends to crystallise the shank and, on many occasions shanks of 1¾ in. and 1½ in. thick section break at a position where they protrude from the tool box. Therefore, when using copper for the heavy duty tools, it is preferable to preheat in a high temperature furnace at approximately 1,100°C. (it is essential to have a de-oxidising atmosphere existing in both these furnaces).

composition of tool-tipping section

All the usual machine tools and accessories associated in the making and re-conditioning of carbide tools are needed under this heading and include the following: toolpost grinders, surface grinders, tool and cutter grinders, profile grinders, milling machine, furnaces, and so on.

When tools of the larger section are returned from the machine shops with broken tips, the tips are taken off and cut up by means of a diamond wheel on an Asquith[4] carbide cutting-off machine. They are then segregated and placed in bins bearing the various manufacturers' names and grades. They are then utilised for producing tools of smaller section—drills, etc. One tool introduced, using broken bits. is a parting-off tool, and is now in general use. These can also be utilised as grooving tools for such work as cutting oil throws in rolls. In addition to this, many tools can be made quickly, thus avoiding the delay in obtaining supplies of tips from the manufacturers when tools are urgently required. It is therefore apparent that a great saving in carbide is obtained.

methods of control of tool utilisation

Carbides are expensive tools and since, at the Author's works, between 1,000 and 1,200 per month are provided, some method of control is essential to prevent waste of time and money. This is achieved as follows: cutting tools listed in the manufacturers' manuals of standard tools are marked for identification purposes with an abbreviated form of manufacturers' trade mark, a tool number and the grade of carbide used, e.g. Tool No. 778 tipped with Cutanit Grade R[2] bears the marking C/778/R. The cutting tools are carried in the toolroom stores and when the stock reaches a certain agreed low level, re-ordering takes place. Special tools originally designed for the machining of certain products have now become standard tools to the users and hence have been allocated an identity number. They have also been included in a brochure issued to the managers and foremen of the machine shops concerned.

factors involved in deciding suitable applications

suitability of machine tools

In selecting machine tools which lend themselves to the exploitation of carbide tools, certain factors require consideration; they should be powerful and rigid, or in other words, specially designed to this end. However, problems encountered in the heavy machine shops are vastly different from those in quantity production shops, and there are probably many good reasons for maintaining in operation machine tools which appear to have reached the end of their useful life. Workpieces, sometimes weighing many tons, often unbalanced, and creating steady support problems when being turned, impose limitations in speed rotations. Quantities required are often small and the employment of special purpose machines becomes uneconomical, so that the machine tools mostly utilised in the heavy type machine shops are of the following nature:

1. General purpose lathes.
2. Planing machines.

3. Radial drilling machines.
4. Boring machines.
5. Horizontal boring machines.
6. Vertical turning and boring mills.

The successful working of the older type of machine depends a great deal on the skill of the operator. Machine tools for machining large workpieces represent a considerable capital outlay, and for economic reasons must frequently be kept in operation for periods of twenty years or more. Many of these machines are, at the present time, taking advantage of carbide tools, not in the sense of machining at terrific speeds, but in the cutting of the harder steels which would have been very difficult to achieve with conventional tools a few years ago. In many instances, the machine tool has to be altered to suit a particular workpiece and sometimes many unique features are incorporated. In regard to old machine tools, instances can be quoted of some machines which have been in use for about thirty years and are now using carbides. In fact, at the Author's works there are installed four tyre turning lathes of this vintage which at the present time are successfully turning workpieces of manganese steel, seven and eight feet in diameter. These machines are double-ended, having two face plates enabling two workpieces to be turned at the same time. The time taken on one of these lathes is approximately equal to the time taken to machine one workpiece on a modern vertical mill.

Centre lathes, horizontal borers, vertical turning and boring mills are continually being installed. At the present time carbide tools are applied to almost every type of machine tool except old belt driven machines which, fortunately, are now only few in number.

In summing up, the older type of machine has to be assessed in regard to the use of carbide tools and the following would appear to be necessary features in older machine tools to enable carbide tools to be satisfactorily applied:

1. the machine must have self-contained motor drive of sufficient horsepower;
2. the machine must have a range of feeds and speeds;
3. the slides and bed of the machine must be in good condition;
4. adequate bearing support for headstocks, etc., must be available;
5. live centres must be used.

One good point in their favour is that the type of machine shop having these old machines usually has to deal with a great number of products within the low speed range and, in most cases, carbide tools can be efficiently utilised.

types of material to be machined

The main products of the steel industry requiring finishing by machining are castings, forgings, rolled plates and bars. Non-ferrous metals often present machining problems, but are not produced in the same quantities as steel.

This vast field has been available for the exploitation of carbides, hence a great deal of experimenting has been carried out over the past twenty years. As a result, the following conclusions can be drawn:

1. a particular make of carbide has an affinity for a specific type of steel;
2. different grades of carbide are satisfactory for steels at various stages of manufacture especially in regard to heat treatment;
3. machining castings is always more difficult than machining forgings, due to sand inclusions in castings resulting from their manufacturing processes.

A few examples from each group will now be considered.

(*a*) *machining of forgings*

A tungsten titanium grade tool was used to machine a carbon chrome forging in the 45/50 tons condition. The cut was intermittent and averaged 1 in. in depth, after which the tool condition was such that it could be re-ground.

Generally speaking, carbides will not absorb a great deal of shock before fracture occurs.

Many other makes of carbide have been tried on similar operations, but when the tool has been removed, the tip in most cases has been found to be cracked at the depth of the cut.

Some typical figures used are:

Diameter of workpiece	:	20 in.
Length	:	8 ft.
Speed used	:	136 ft. per minute.
Feed used	:	0.020 in. per rev.
Average depth of cut	:	1 in.

Probably there are available several makes of carbide capable of cutting the above material in keeping with the figures given, but experience has shown that one particular brand has been outstanding on this operation; therefore, this type has been adhered to.

(*b*) *machining of heat-treated forgings and castings*

Carbides have been successful in machining workpieces in this class, which would previously have been done by grinding or, in some cases, have been classed as unmachinable. There are two types of carbide which have been most successful in machining steels in the heat treated condition, viz.:

1. The grade for finish machining steels (tungsten titanium).
2. The grade for turning chilled iron rolls (tungsten carbide).

Generally, the maximum hardness figures of workpieces capable of being machined are in the region of 500 Brinell, but in certain isolated cases workpieces having figures exceeding this value have been machined, but not without a great deal of care and patience.

machining with the tungsten titanium grade of carbide

The operation of turning carbon chrome steel rolls, heat treated to 300-350 Brinell, is performed quite satisfactorily with this grade of carbide and is now an everyday production job. Typical figures are:

Diameter of roll	:	19 in.
Length	:	42 in.
Speed used	:	98.8 ft. per minute.
Feed used	:	0.004 in. per rev.
Depth of cut	:	$\frac{5}{32}$ in.

Two unusual screwing applications are quoted where this grade of carbide has greatly assisted in the production of:

(*a*) stainless iron nuts having a hardness specification in the range 300-350 Brinell. High speed tools performed this operation quite efficiently in the lesser range, but when the hardness approached the maximum of 350 Brinell, high speed tools failed and carbides were successfully introduced. The size of the tool used was $\frac{1}{2}$ in. dia. by $1\frac{1}{8}$ in. long, necessitating solid pieces of carbide ground to the appropriate angles.

Details of the thread called for were:
Two start acme $\frac{3}{8}$ in. pitch $\frac{3}{4}$ in. lead. Carbide tipped drills used for drilling bore of thread diameter:

Dia. of bore of thread	:	$1\frac{3}{4}$ in.
Length	:	3 in.
Depth of thread	:	0.2 in.

(*b*) Screwing bolts of heat-resisting steels in a No. 1A Ward[5] capstan lathe, using a die head, had been attempted, but without success. As an experiment, the high speed segments of the die head were annealed, milled, tipped with carbide and threads formed on these segments by means of thread grinding. The thread required was $\frac{1}{2}$ in. dia. BSW. 2 in. long. The die head, after modification, successfully screwed the heat-resisting steel bolts.

In conventional screw cutting applications, high speed tools in most cases are superior to carbides where the weakness of the point leaves a lot to be desired.

In summing up the two aforementioned screwing operations, the main feature to note is that the introduction of carbides enabled the operations to be carried out successfully and thus avoided the necessity of having to re-anneal the work pieces in order to do the job by normal methods.

machining with the tungsten grade of carbide

Several tungsten carbide grades are available for machining different materials, but in cutting certain steels in the heat-treated condition, the grade normally recommended for turning chilled iron rolls has been of great assistance and has enabled machining operations to be carried out successfully. Examples are given below:

1. Oil throw grooves situated at each end of the barrel of a carbon chrome steel roll, hardened to 95 Scleroscope (850 V.D.P.H.) have been cut, using tungsten carbide tools. These oil throws were machined in after heat treatment, because it was feared that cracking would occur around this area if the grooves were cut prior to hardening. The cutting was accomplished, but not without great perseverance, and some eight tools were needed for each oilway. In fairness it should be pointed out that the tool was weak in design because of the small size of the oil throws which were $\frac{1}{4}$ in. deep by 70 degrees inclusive angle. The machining details were:

Dia. of workpiece	:	20 in.
Speed used	:	10 ft. per minute.
Feed used	:	Plunge cutting by hand.

This operation is not one to be recommended, chiefly because of the high costs incurred in making and re-grinding the tools and also on account of the length of time required for the actual operation. Nevertheless, it does show that carbides were capable of completing this particular operation.

2. Carbon manganese steels heat-treated to 350-450 Brinell, particularly hollow forgings, have been machined quite easily by tungsten carbide tools, especially where certain operations are carried out after heat treatment. Brinell hardness figures can sometimes be misleading, particularly with regard to machining properties; for example, manganese steel has a low Brinell hardness figure, but it is tough to machine. It is the machinability of the material that is important, since certain heat treated steels, up to and including 350 Brinell, can be quite easily machined, yet manganese, with a Brinell of approximately 200, is extremely difficult.

machining of steel castings

One well-known manufacturer has developed a grade of carbide for machining steel castings, and tools made from this grade of carbide, with a negative front to back rake, have proved very efficient. The grade used is one of the tungsten carbide class, and when employed on turning cast steel pilger rolls, proved far better in all respects than the titanium grades, showing less wear and longer life. No hard and fast rules, however, can be laid down for the grades of carbide necessary for satisfactory machining of castings. For instance, the only grade which will successfully machine manganese steel is one of the titanium class, but in planing, the grade normally recommended for wood cutting tools has proved most efficient, probably because the cutting tool is subject to severe impact loading during planing.

One specific conclusion the Author has arrived at in regard to machining steel castings is that cutting tools must be designed with a negative rake.

machining manganese steel

Manganese steel was invented by Sir Robert Hadfield, Bart., F.R.S., in 1882[7], and for many years was considered unmachinable on account of its properties of toughness and deformation hardening (work hardening), and the only means of finishing this steel was by grinding.

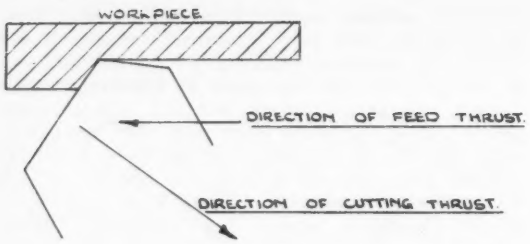


Fig. 8. Diagram showing thrust taken by the bed of the lathe and not by the lead screw.

The development of cemented carbide cutting tools has made machining and drilling of high manganese steel (12 to 14 per cent. manganese) possible, not only theoretically but commercially. It should be borne in mind that high speed cobalt steel tools will cut manganese steel with a fair amount of success, their chief fault being that should it become necessary to take out the tool for re-grinding, the greatest difficulty will be experienced in picking up the cut again. Cemented carbide tools have overcome this problem and are now used for turning, planing, boring, slotting, shaping and screw-cutting, and over the past few years have proved themselves to be the best medium for cutting manganese steel. The machine tools employed must be rigid and the workpiece securely held. It is also important to prevent chattering of the tool or workpiece in order to avoid damage to the cutting edge.

design of carbide tools

The form of the tool is of paramount importance and, if incorrect, will almost inevitably cause jarring and chattering, resulting in the complete failure of the tool. With certain exceptions, all tools are made with a negative front to back rake, varying from 10° to 45°. The function of the negative rake is to direct the chip thrust into the body of the tool and away from the cutting edge where the tip is weak, and to break up the turnings. The tool should have a relatively small radius at the point to give minimum interference with the straight line cutting edge and at the same time to ensure that the thickness of the chip does not taper off too slowly, since if this happens rubbing will occur, and rubbing, once started, can only be prevented from spreading along the tool edge with the greatest difficulty. After much experiment, it has been found that the most suitable grade of carbide for all types of machining of manganese steels is tungsten titanium.

application of the tools and importance of correct direction of thrust

Correct procedure in setting the tool to the workpiece is as important as the correct tool form. Extremely heavy pressures are necessary in the machining of manganese steel, and the main object should always be to transfer the tool thrust as far as possible to the machine slides rather than allow it to be taken by the feed mechanism. This is shown in Figs. 8 and 9[7].

When machining cast manganese steel, care must be taken to ensure that the cut gets under the skin, otherwise skidding and rubbing will occur, resulting in failure of the cutting edge. The tools must be firmly secured with the minimum amount of overhang in order to prevent chatter. In all operations cutting is done perfectly dry. With regard to machine tools, use has been made of many of the older types of machines which, after having been thoroughly overhauled, have been capable of carrying out these operations on similar lines to more modern machines. To a certain extent many shapes of tools will cut manganese steel, but the design of tool illustrated in Fig. 10 has been the most successful and the most economical.

examples of machining manganese steel workpieces

1. turning and boring manganese steel bushes

These are cast in halves and assembled in dredger buckets as a complete bush. Until quite recently the only method of finishing was by grinding, and the

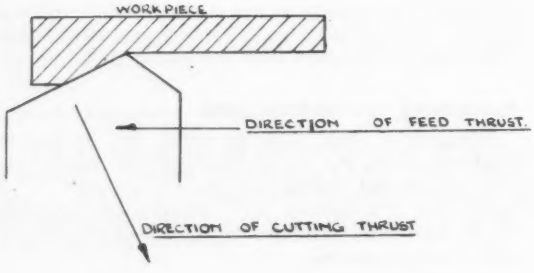
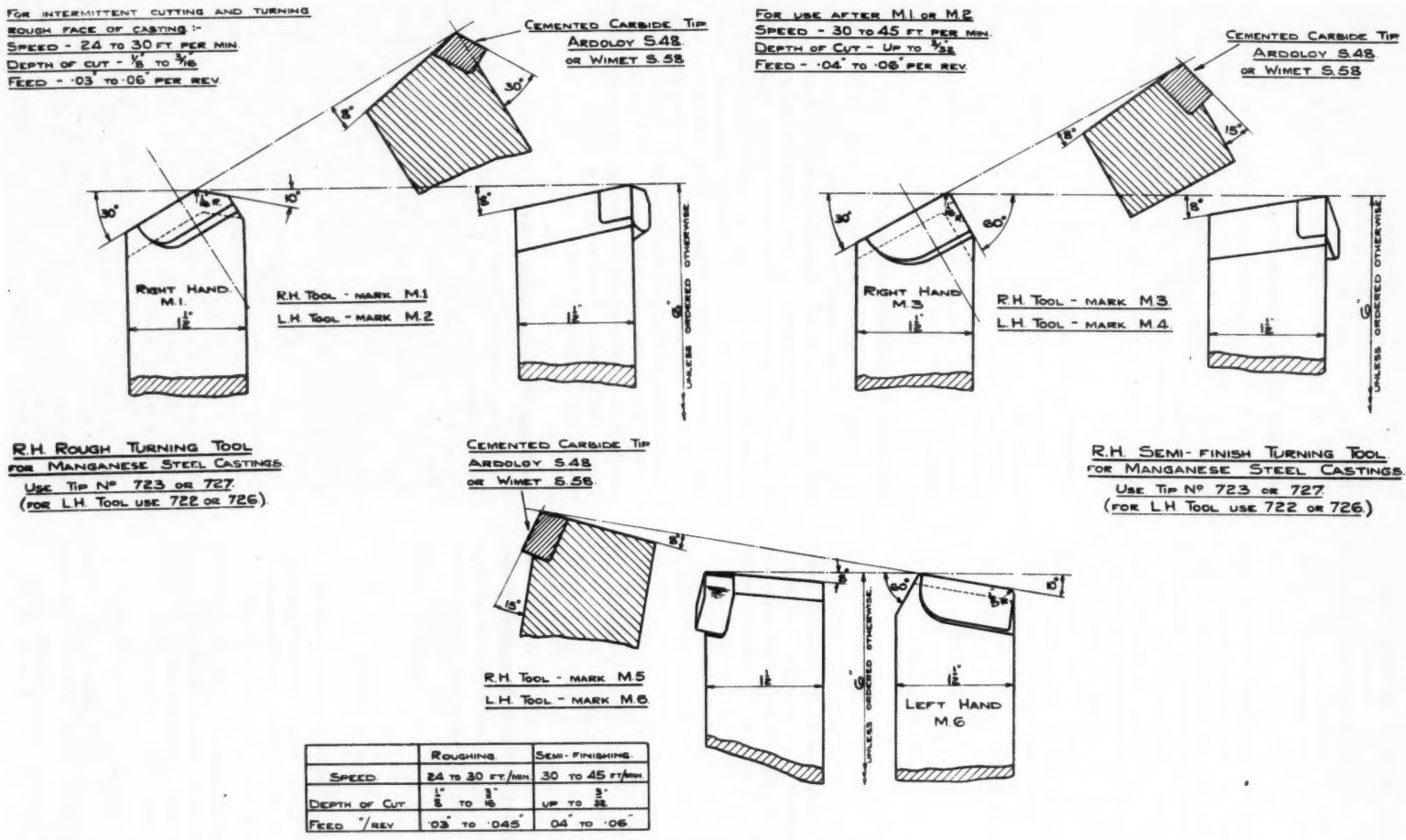


Fig. 9. Diagram showing heavy thrust taken by lead screw. The tool, because it trails, will cut with a crowded action.



	Roughing	Semi-finishing
Speed	24 to 30 ft./min.	30 to 45 ft/min.
Depth of cut	1/8" to 5/16"	up to 3/32"
Feed "/rev.	.03" to .045"	.04" to .06"

Fig. 10. Tipped tools for machining manganese steel castings (Scale : full size).

number of wheels used for this operation ran into the region of 20 per day. It therefore became essential for economic reasons to try other means of finishing. Turning was attempted and after many teething troubles the job was successfuly accomplished.

The method adopted was as follows: the half bush was housed in a fixture on the table of a horizontal boring machine and the tool was revolved in a boring bar supported by a bearing in a pedestal situated at the rear of the machine. The tool shape was the same as that used for machining manganese steel, the only difficulty encountered being that of finding a suitable make and grade of carbide to stand up to this arduous task. After trying several brands the right one was eventually found, thus enabling the process to become a regular production job.

The machining details were:

Bore of bush	:	6 in. diameter.
Length	:	14 in.
Speed used	:	31.2 ft. per minute.
Feed used	:	$\frac{1}{32}$ in.
Depth of cut	:	$\frac{1}{8}$ in. and $\frac{3}{16}$ in.

The next operation on the bush was turning the outside diameter. This was done in a centre lathe, the bush being attached to a mandrel. The tool used for this function was similar in design to the one used for boring, differing only in the shank section which was larger.

The machining figures were:

Diameter of workpiece	:	8 in.
Length	:	14 in.
Speed	:	62.4 ft. per minute.
Feed	:	$\frac{1}{32}$ in.
Depth of cut	:	$\frac{1}{8}$ in. and $\frac{3}{16}$ in.

2. *machining manganese steel Bowle liners and mantles*

The outside diameters of these liners varied from 4 ft. to 7 ft. They were machined on double ended face plate lathes. Roughing and finishing cuts were taken, the outside and inside diameters being cut separately.

The machining figures were as follows:

		Roughing	*Finishing*
Speed used	:	25/30 ft. per min.	30/45 ft. per min.
Feed used	:	.03/.06 in. per rev.	.04/.06 in. per rev.
Depth of cut	:	$\frac{1}{8}$ in./$\frac{3}{16}$ in.	up to $\frac{3}{32}$ in.

By comparison, the figures for machining a 6 ft. diameter Bowle liner on a modern Richards vertical turning and boring mill, on which both diameters can be cut simultaneously, are:

		Roughing	
Outside diameter (6 ft.)			*Inside diameter* (5 ft. 6 in.)
Speed	:	48.29 ft. per min.	44.25 ft. per min.
Feed	:	.031 in.	.031 in.
Depth of cut	:	$\frac{1}{8}$ in. to $\frac{3}{16}$ in.	$\frac{1}{8}$ in. to $\frac{3}{16}$ in.

		Finishing	
Speed	:	62.712 ft. per min.	54.88 ft. per min.
Feed	:	.031 in.	.031 in.
Depth of cut	:	up to $\frac{3}{32}$ in.	up to $\frac{3}{32}$ in.

slotting of manganese steel

In slotting manganese steel workpieces, the tools have a neutral rake, i.e. flat top, and are fitted in a compressed air bar. The purpose of using a bar of this design is to prevent the detachment of the tip during the return stroke, as it is necessary to provide some means of lifting the tool from the machined surface.

screwing manganese steel

Screwing manganese steel, both externally and internally, is done by a single-pointed tool, the procedure being as follows: the thread is roughed out, using a tool having 10° negative front to back rake and then finished with the aid of a flat top tool ground to the correct angles.

planing of manganese steel

Manganese steel rails 10 ft. long. The table traverses at the speed of 27 ft. per minute. Depth of cut $\frac{1}{8}$ in. to $\frac{3}{16}$ in. Feed per stroke .015 in.

In this operation the tool should be raised quite clear of the work on the return stroke, whilst the table should be as steady as possible to minimise chatter. In addition the planing machine should have an all-geared drive. A large negative front to back rake of 45° is employed on the tool, ensuring a low shock loading at the beginning of the stroke, thus reducing the risk of breakage. The tools should project as little as possible beyond the clamps since overhang increases the likelihood of chatter. Fig. 11 illustrates this planing tool.

drilling of manganese steel

Drilling machines used for this work should be of rigid construction and preferably of the pillar type, but radial arm drills have been used with some success. The head should be kept as close to the pillar as possible to ensure maximum rigidity. When drilling with super high speed drills, tremendous pressure has to be exerted, e.g. a 1 in. drill requires a thrust of approximately 7,000 lb. to effect penetration. Continuity of feed is important, since if this is interrupted, further drilling is difficult as the material work hardens. If a standard high speed drill is re-ground to the original cone angle, it immediately comes in contact with the work hardened surface which tends to blunt the cutting edges with subsequent failure of the tool. The difficulties experienced with high speed drills have been overcome by substituting carbide tipped drills.

The conventional type of carbide tipped drills, made by the leading manufacturers, were first tried at the Author's works, being made up by milling a slot in the end of the drill body, brazing in a carbide tip and grinding to the correct angles. This drill had several disadvantages, as the drill body or shank

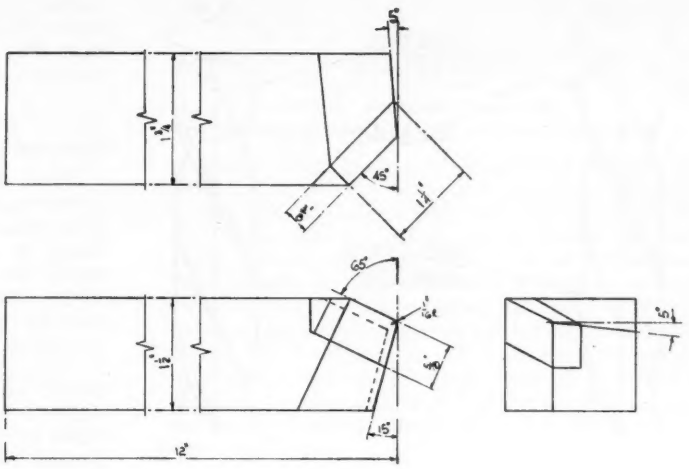


Fig. 11. Manganese planing tool (Scale: full size).

was made of carbon steel and tended to wear after a number of holes had been drilled. This was particularly noticeable when drilling deep holes in castings. In addition, the slot tended to enlarge after a certain amount of use. The tip itself, being very thin and weak at the point, often cracked, thus bringing about failure.

To surmount these troubles, the Author devised a simple carbide drill by butt brazing a piece of carbide to the end of a high speed twist drill, using silver solder. The drill was then ground to the required sizes. This drill is now used very successfully. During its early development, however, trouble was encountered due to detachment of the tip when penetrating the manganese steel workpiece. To combat this soluble oil was used, its main function being to preserve the weld junction of the tip to the shank. As the operators became "manganese steel minded" with regard to this type of drilling, the trouble was largely eliminated. The drill is ground to give an inclusive cone angle of 150° as against the standard 118° on the high speed twist drill, so that when the drill is fed down, the bridge or chisel point first makes contact over a small area. As penetration progresses, the whole cutting edges of the drills are rapidly brought into action due to this larger obtuse angle.

The sizes recommended for this type of drill are from $\frac{3}{16}$ in. to $1\frac{3}{8}$ in. diameter (although for certain special applications, drills as low as $\frac{1}{8}$ in. have been used). It should be realised, however, that the smaller the drill the less area of contact is available for the weld. Therefore, it is difficult to ensure a strong joint. Drills of $1\frac{5}{8}$ in. diameter have, however, been used successfully.

Another satisfactory alternative design is one in which a spigot is ground on the tip. This necessitates grinding a corresponding slot in the high speed twist drill in order to seat the tip. To mill a groove in a twist drill would require annealing of the drill and subsequent re-hardening. The drill manufactured on these lines proved very efficient, as the spigot helps to resist the torque applied. It has, however, certain disadvantages, since the design cannot be applied to the smaller diameter drill, and is much more expensive to make. For certain requirements, special tips 1 in. dia. and above have been obtained from the manufacturers with the flutes sintered, and tips having both sintered flute and spigot have also been supplied. The butt brazed drill, however, is more popular and is used mostly on account of the ease of manufacture.

The main features to note about carbide tipped drills are as follows:

1. the drill should be short and stubby, in relation to the depth of hole to be drilled;
2. old and broken pieces of carbide can be utilised;
3. old high speed twist drills can be used in the manufacture of carbide tipped drills;
4. carbide-tipped drills require less thrust or pressure;
5. hand feed can be used;
6. coolant can be used;
7. the high speed shank will stand up to the tough drillings and continual rubbing so, therefore, a longer tool life is obtained than with carbon steel shanks;
8. drills after being taken out can be re-ground and will immediately pick up the work-hardened surface of the material being drilled.

Cemented carbide tipped drills are shown in Fig. 12.

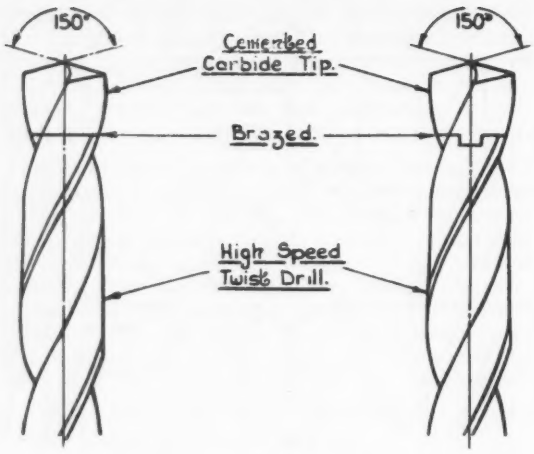


Fig. 12. Cemented carbide tipped drills

comparisons of carbide and super high speed drilling

Material : Rolled manganese plate ½ in. thick.
Dia. of holes to be drilled : 11/16 in.

Super high speed	*Cemented carbide*
Drill revolves at 40 r.p.m.	Drill revolves at 390 r.p.m.
Feed 90 revs. per in. traverse.	Feed 70 revs. per in. traverse.
Holes per re-grind 10-15.	Holes per re-grind 25-30.

examples of drilling with carbide tipped drills. manganese steel pins.

Dia. of pin : 1 in.	Dia. of pin : 1½ in.
Dia. of drilled hole: ¼ in.	Dia. of drilled hole: 7/16 in.
Feed : hand	Feed : hand
Drill working at 390 r.p.m.	Drill working at 390 r.p.m.
Holes per re-grind: 90	Holes per re-grind: 40

manganese steel castings

Two examples are given below:
1. A number of 1⅛ in. dia. holes 3 in. deep were required to be drilled in a tumbler. These were drilled in a normal manner at 150 revs. per minute, the feed being controlled by hand. No undue difficulties were encountered, but two holes only were obtained before re-grinding of the drill became necessary.

2. Drilling 1 in. dia. holes, 7/8 in. deep, in points and crossings; 16 holes were drilled at a speed of 150 revs. per minute before re-grinding of the drill was necessary. Hand feed was employed.

A patent has now been taken out for the drill used in these operations.

Countersinking can be carried out more efficiently with specially designed super high speed drills ground as countersinks, than with carbide drills. Drills should be ground with the minimum possible clearance to avoid excessive chatter, and probably the bigger cutting area tends to cause the failure of carbide drills. To use carbide drills with success, a pilot must be employed if possible. This operation is definitely one where high speed scores over carbides.

future of cemented carbides in relation to ceramic oxides

Since their introduction, approximately thirty years ago, cemented carbides have achieved remarkable successes and have more or less assumed ascendancy in modern machine shop production. The search for cutting materials which will permit still higher cutting speeds has been intensified over the past few years, and certain ceramic materials offer possibilities in this direction. Increasing attention is being paid to the potentialities of these tools by all the leading industrialised countries of the world, where research and active developments are taking place in this sphere. Their place in the heavy and general engineering machine shop appears to be at present primarily that of a finishing tool where hard steels have been successfully machined. Possibly in the future they may enable many a grinding operation to be dispensed with.

examples of finish machining with ceramic oxides

carbon chrome steels (0.8% carbon).

1. Dia. of workpiece	6 in.
Length of workpiece	46 in.
Hardness	460 Brinell
Speed in ft. per min.	390
Feed per rev.	0.010 in.
Depth of cut	0.06 in.
2. Dia. of workpiece	10 in.
Length of workpiece	35 in
Hardness	595 Brinell
Speed in ft. per min.	234
Feed per rev.	0.010 in.
Depth of cut	0.06 in.
3. Dia. of workpiece	19.5 in.
Length of workpiece	56 in.
Hardness	350 Brinell
Speed in ft. per min.	507
Feed per rev.	0.012 in.
Depth of cut	0.09 in.

tungsten chrome molybdenum steel

Dia. of workpiece	19in.-15in. (taper)
Length of workpiece	38 in.
Hardness	380 Brinell
Speed in ft. per min.	424.84-335.4
Feed per rev.	0.010 in.
Depth of cut	0.06 in.

nickel chrome molybdenum

Dia. of workpiece	6 in.
Length of workpiece	24 in.
Hardness	600 Brinell
Speed in ft. per min.	400
Feed per rev.	0.006 in.
Depth of cut	0.06 in.

In the above operations the tools when taken out were in quite good condition, most of the damage to the tip being caused by flying chips and in all probability several of the examples could have been machined faster if the speed had been available in the machine tools involved. The maximum hardness machined up to the present time was a carbon chrome steel roll, heat treated to 800 V.D.P.H. The machining figures being as follows:

Dia. of roll	6 in.
Length of roll	36 in.
Speed in ft. per min.	70.2
Feed per rev.	0.009 in.
Depth of cut	0.06 in.

The wear on the tip was negligible.

A second cut was then taken, increasing the speed to 109.2 ft. per min., depth of cut to 0.09 in.; with the feed per rev. remaining the same this pass caused chipping of the cutting edge of the tip. Experiments are continually being made in machining special steels such as manganese rolled bar, boron, etc.

In comparing carbides with ceramics, both types of tools should find their own field of activity in the machine shop and also have their advantages, which are as follows:

carbides are stronger and in their speed range are superior. They will withstand more severe conditions, for example, in rough machining which entails intermittent cutting.

ceramics. One grade will machine a variety of materials as distinct from carbides where different grades are required. They will cut harder steels and give a superior finish. No coolant is required (unless to cool the workpiece). As at the present time carbides are complementary to high speed steel tools the future trend would appear to be a carbide speed range, a range of speeds for ceramics and where carbides leave off ceramics will take over. However, it is quite obvious that machine tools will have to be designed to take full advantage of ceramic oxides for they will surely introduce an age of ultra high speed machinery.

acknowledgment

The Author wishes to thank the Directors of Hadfields, Ltd., for permission to publish this paper.

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design and performance of two
MILLING FORCE DYNAMOMETERS — concluded from page 742

not, however, appear excessive and further work will be carried out in order to investigate whether or not for practical purposes it may be possible to work on a relationship, independent of the helix angle, between the specific cutting pressure and the middle chip thickness.

The work described in this Paper was carried out in the Royce Laboratory of The Manchester College of Science and Technology, and the authors would like to thank Professor H. Wright Baker, Head of the Department of Mechanical Engineering, and the National Research Development Corporation, who sponsored part of the research work, for permission to publish this report. Thanks are also due to the authors' colleagues in the Laboratory and on the N.R.D.C. Research Team for their co-operation, particularly Messrs. D. L. Leete, B.Sc., A.M.I.E.E., R. L. Nicholson, S. M. Said, Ph.D., I. Skorecki, M.Sc.Tech., A.M.I.Mech.E., and A. Williams.

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Apprentice Training

by F. Rushton, A.M.I.Prod.E.

Apprentice Supervisor,

The de Havilland Aeronautical Technical School,

at Lostock, Bolton.

In this article Mr. Rushton describes some projects carried out by boys in the Apprentice Training School.

The projects were produced to give the maximum opportunity to boys showing the greatest rate of progress.

THE projects about to be described in this article were carried out in the Apprentice Training School at the works of de Havilland Propellers Limited, Lostock, Bolton, which forms a branch of the de Havilland Enterprise, where the Author has the privilege of being Apprentice Supervisor. The boys concerned in the experiments are all boys in their first year in industry after leaving school which, in the case of the de Havilland Enterprise, is spent in the respective training school. Its members vary widely in age and academic achievement, the extremes being boys from Secondary Modern schools, not having taken any assessed examinations and following Craft courses, to boys from Grammar schools with successes at "A" level and reading for London external B.Sc. degrees.

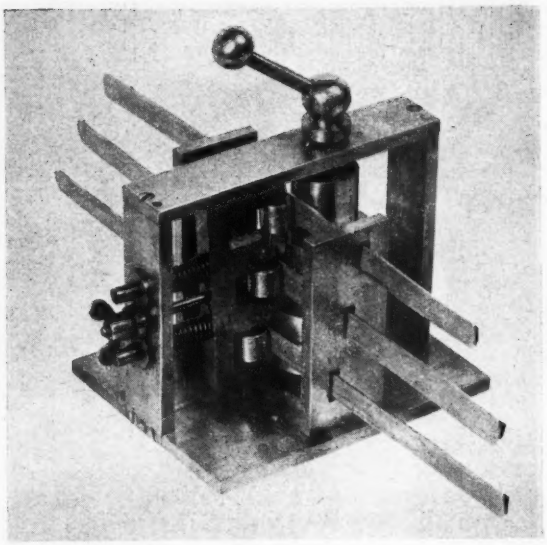
During the first twelve months in the Apprentice Training School the boys follow a curriculum which includes machining, fitting, drawing, sheet metal work, welding, moulding, together with allied lectures, and, as is to be expected, the rate of progress varies, the boys forming themselves into one of three categories:

(*a*) The bulk, usually about 80 per cent., whose progress varies from satisfactory to good;

(*b*) a group, usually about 10 to 12 per cent., whose progress varies from poor to satisfactory, some of whom will require an extended probation period;

(*c*) the remainder of a given intake, whose assimilation and progress will be very high.

In an attempt to develop the natural talent, both practical and technical, of this latter group a system



See Project No. 1.

of projects was initiated: the idea is to give a boy, or boys, a principle to illustrate by some basic method, the boy or boys being required to submit a design of their proposed method to achieve it, then to draw it, and finally to manufacture and test it, without any priority on the plant available. Some of the projects which have been undertaken were demonstrated at the Summer School which the Royal Technical College, Salford, held in July, 1956, where the Author gave the final paper, entitled "Education and Training for Machine Shop Efficiency", and where considerable interest was shown, a number of the audience taking sketches for possible application within their own organisations.

Of the many projects undertaken the following embrace a fair cross-section of the type of work carried out:

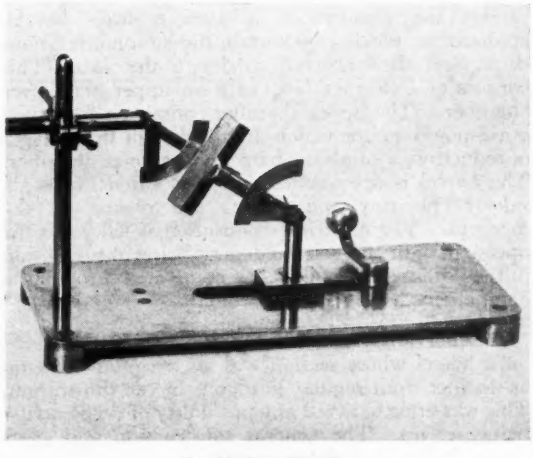
Project No. 1. To demonstrate the relationship between surface speed and diameter.

The object of the exercise was to produce a simple mechanism which would demonstrate clearly to completely inexperienced adult labour the relationship mentioned. The mechanism consisted of a stepped cone with its axis in the vertical plane and lying between a base plate and an upper end plate; this cone could be rotated by a small handle, and a spring loaded ball is inserted in the upper face of the stepped cone and between the end plate. A recess in the end plate receives the ball so that the stepped plate is capable of having one complete revolution carried out. Two slotted frames freely support three strips, one on each step of the cone, with their axes at right angles to the axis of the cone. The strips are pressed to friction tangential contact with their respective steps of the cone by the action of a spring loaded plunger. Thus, as the stepped cone is rotated, the strips will be passed through the supports at a rate proportional to the diameter of the particular step, starting from a common datum. A rotation of the cone demonstrates the required principle.

After manufacture of the prototype the boy encountered difficulty in obtaining immediate movement of the strips at the commencement of rotation, and modification was therefore carried out by cementing thin rubber pads on the contact faces of the strips and the problem of initial slip overcome.

Project No. 2. To demonstrate to Tool Room personnel that in certain types of universal milling any desired acceleration may be obtained as the function of an angle.

Plate cams for automatic lathes are normally produced by hand from blanks graduated radially in 1/100 of a circle, the ordinate for each particular radius being scribed on a curve resulting from connecting up of each intersecting mark. Because of the numbers involved it was decided to produce some of these by milling. The blank was mounted on a dividing head with its spindle in a vertical plane geared up to the longitudinal table feed on a horizontal milling machine equipped with vertical head attachment. In calculating the gear trains to give required acceleration for particular lobes of the cam, it was found that only rarely could this be done with a sufficient degree of accuracy, and that the smallest possible variation of the gear train, i.e. one tooth, produced the effect which was either too great or too small. In order to break down the limitation produced by one tooth variation, it becomes necessary to incline the workpiece and the cutter at mating angles; the table travel then becomes the hypotenuse of a right-angled triangle and by suitably equating the table-travel and the desired acceleration, we obtained the sine and thence the angle at which to incline the object and the cutter to give the required effect.



See Project No. 2.

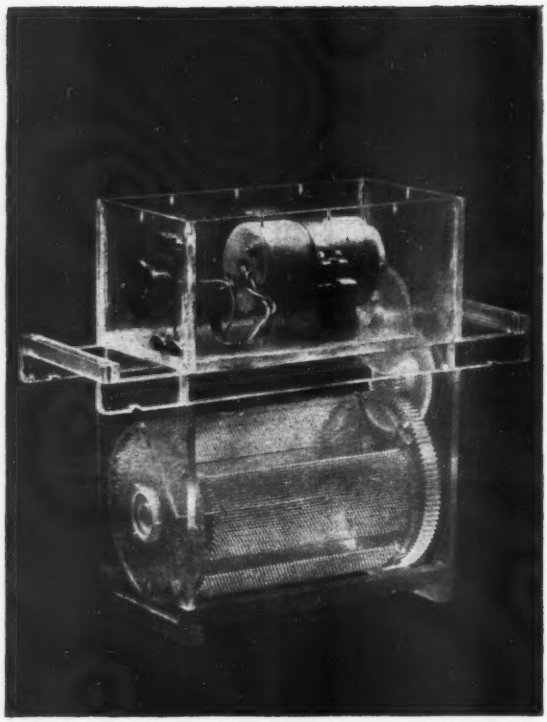
The mechanism produced in this case consists of a base plate on which is mounted a movable block to represent a milling machine, movement of which is achieved by rotating a cam against a spring. This ensures that for all considerations the movement is constant from minimum to maximum. The block carries a column on which is mounted a graduated scale which can be inclined at any given angle against a fixed protractor, this scale represents the workpiece. The base plate also carries a fixed column towards and away from which the block travels when moving. On this column is mounted a stud which can again be inclined at any given angle and to mate with the graduated scale on the movable block; this stud represents the cutter. By suitably setting the datums and moving the table mechanism through one revolution, the passage of the cutter across the workpiece can be measured and by repeating the procedure at different angles, selected at random, it will be seen that the travel of the cutter across the workpiece has varied, thus demonstrating that the limitation imposed by a one tooth variation has been removed and that any desired acceleration can be obtained.

Project No. 3. To manufacture a small electroplating barrel for small components.

Several years ago the Apprentice Training School was approached by the Laboratory regarding the possibility of manufacturing the above item, of which it was in great need, due to difficulty of suspending by orthodox method. None of the type required was manufactured in this country so far as could be ascertained and restrictions on dollar imports precluded purchase from the U.S.A. Only illustrations in American trade journals were available as a general guide. The object seemed to possess some interesting possibilities, and its manufacture was, therefore, undertaken and given to two apprentices as a project.

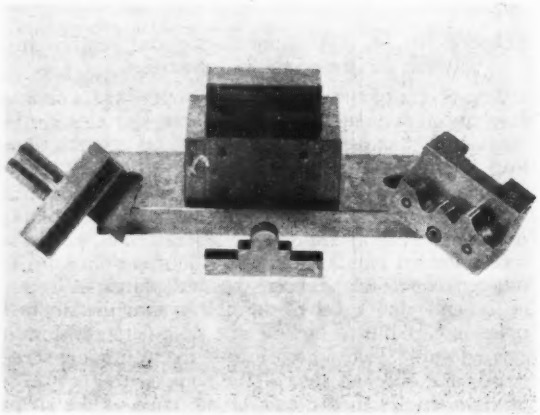
The only information given to them was the type of component required to plate and the pictorial illustrations referred to. Their approach was to project the illustrations in various ways by an epidiascope, picking up certain dimensional relationships, and then proceed to design the unit. This consists of a Perspex box, with an upper and lower chamber. The upper chamber contains a fractional horse-power motor which drives, though three stages of reduction, a tumbling barrel in the lower chamber. The barrel is open-ended and perforated on its six sides. The tiny components are placed in the medium. The electrical connection is led in to the open end of the barrel, the deposit being in suspension in the liquid, and the circuit is completed through the components as they tumble round.

In their analysis of the design, the boys decided on a barrel whose section was an irregular hexagon as distinct from regular hexagons in the illustration. This was done to avoid any possibility of cyclic action being set up. The general construction and gears are in Perspex for obvious reasons.



See Project No. 3.

Project No. 4. Some years ago the supply of soft aluminium wire was severely restricted and the works' Plating Department was seriously embarrassed, as this was used as a medium for the suspension of many components into the plating vats. In order to overcome this use was made of strips from aluminium off-cuts, slotted to receive components, one end being bent into the form of a hook for suspension into the



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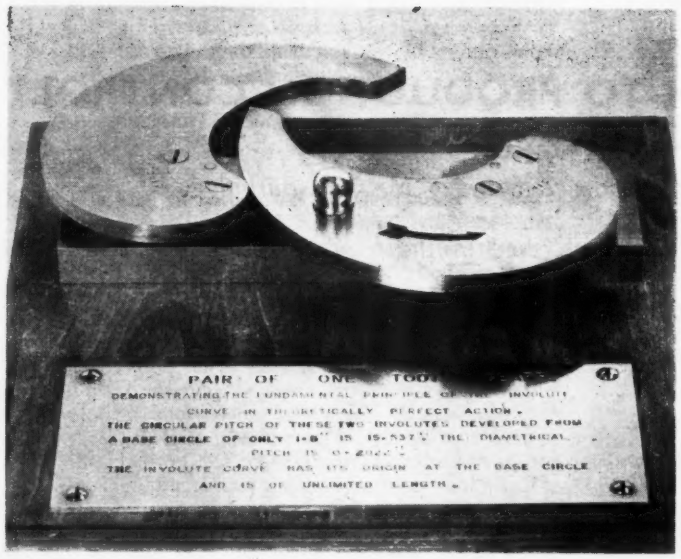
PAIR OF ONE TOOTH
DEMONSTRATING THE FUNDAMENTAL PRINCIPLES OF THE INVOLUTE
CURVE IN THEORETICALLY PERFECT ACTION.
THE CIRCULAR PITCH OF THESE TWO INVOLUTES DEVELOPED FROM
A BASE CIRCLE OF ONLY 1·8" IS 15·537" THE DIAMETRICAL
PITCH IS 0·202"
THE INVOLUTE CURVE HAS ITS ORIGIN AT THE BASE CIRCLE
AND IS OF UNLIMITED LENGTH.

See Project No. 5.

vat. Due to variations in the thickness of components being plated, a bottle-neck was created in the production of these limited width slots, in the manufacture of which the School was asked to co-operate. After considering the problem, it was decided to crimp the strips in such a way as to employ the natural hoop tension of the material and the job was given to a boy as a project. He produced a punch, die and three forming tools, so that the difficulties were completely overcome.

Project No. 5. Some years ago, the Fellows Gear-Shaper Company set out to demonstrate that, contrary to general belief, the involute curve suffered no limitations and did, in fact, show that it was possible to design a pair of one tooth gears which would maintain pitch contact continuously and satisfy all the required conditions. The difficulty, from a practical and manufacturing viewpoint, was that the clearance required on the idle side of the tooth was such that it passed through or close to the axis about which the base circle was described. The manufacture of a pair of such gears was given as a project to two boys whose academic levels were the optimum difference previously described* but, nevertheless, they worked together in complete harmony, produced the gears mounted in completely satisfactory bearings, and gained tremendously in experience in the carrying out of this project.

* As stated before, the projects were produced to give the maximum opportunity to boys showing the greatest rate of progress. In this particular project an experiment was carried out to observe the pairing together of boys of widely different levels of achievement.

"QUALITY — ITS CREATION AND CONTROL"

Copies of this Report, prepared by a Sub-Committee of the Institution's Research Committee, may be obtained on application to : The Publications Department, The Institution of Production Engineers, 10 Chesterfield Street, Mayfair, London, W.1, price 11s. per copy, including postage and packing.

"A NEW APPROACH TO PRODUCTION CONTROL"

an exchange of correspondence between Mr. J. L. Burbidge, author of the Paper published in the May, 1958, Journal, and Dr. S. Eilon, M.I.Prod.E.

From : **Dr. S. Eilon, M.I.Prod.E.,**
Associate Professor,
Department of Industrial & Management Engineering,
Israel Institute of Technology,
Haifa, Israel.

THERE are many points on which I fully agree with Mr. Burbidge, as can be seen from my previous publications on batch production problems. Our disagreement is partly due to the usage of different terminology, but partly to a difference in the fundamental approach to the problem.

1. It is quite true that the optimum batch size calculation is based on the selection of one single batch for minimum costs per piece, assuming that there is only one such quantity and that naturally it should be selected. Apart from the argument put forward by Mr. Burbidge, one should not forget the practical difficulties of scheduling, which simply cannot yield a logical production schedule compatible with ideal single batch sizes and at the same time achieve a high percentage of machine utilisation. The scheduling of rigid predetermined quantities, which are not dependent on the nature of the plant capacity, cannot result in high utilisation of this capacity and, without specifying the efficiency of equipment utilisation, there is little point in trying to minimise costs for each of the individual items on the schedule. Such a policy may be likened to a situation where meticulous work and time study in a single machine is carried out, when the whole complexities of the general layout and the interconnection of the production centres are completely ignored.

   These considerations have led me to suggest the concept of the production range. The production range is merely an expression of tolerance on the deterministic value of the desirable batch size. It simply means that any batch size within this range is acceptable, when viewed by the specific criteria in question. If the criterion of production costs is adopted and if the curve of production costs per piece is flat, the production range is a wide one and allows for more flexibility when the schedule is planned. I fully agree that many of the cost functions are flat, but not enough data is available to conclude that most cost functions resemble Fig. 2 or Fig. 3 in Mr. Burbidge's Paper. In my view it is dangerous to generalise on this point.

2. On the theorem that minimum production costs lead to maximum profits, I fully concur with Mr. Burbidge. This fallacy is connected with mudding the criteria for measuring results. And here my terminology differs from that of Mr. Burbidge simply by definition. By profit I mean the sum of money that is earned by virtue of selling an article at a certain margin above the production costs. This concept does not take into account the cost of production or investment, nor does it take into account the period of time in which this profit can be realised. The total profit for one batch would, therefore, be the profit margin per unit times the number of units in the batch. It can be shown mathematically * that the batch-size which yields maximum profit is not identical with the batch-size which ensures minimum costs per piece. In fact the maximum profit batch-size is larger, resulting in a lower rate of turnover.

   I fully agree that the term "economic batch-size" has been misused due to confusion of criteria. I would suggest that the economic batch-size is the one that yields maximum rate of return, that is to say, maximum profit per £ invested in producing the batch, per unit time, and I believe that Mr. Burbidge would accept this definition. It is obvious that the turnover is a function of time, and this is one of the basic factors that is not included in minimum-cost batch determination. Again, the economic batch-size, according to the criterion which has just been explained, can be calculated mathematically, and it has been shown ** that indeed the economic batch-size is smaller than the minimum cost batch size. What Mr. Burbidge has tried in his Paper to describe

in general terms has in fact been quantitatively determined, and Mr. Burbidge will agree with me that his suggestion to define the economic batch size as half the minimum cost-batch-size is an arbitrary decision, while the method which I have suggested for economic batch size determination actually optimises the rate of return.

3. Mr. Burbidge made an excellent analysis of the variable *versus* fixed costs and concludes that setting up expense does not vary directly with the number of batches. This observation is certainly true and I would add that the sequence of setting machines as determined by the schedule would also affect the setting costs and many production engineers are familiar with this fact. This does not, however, invalidate the mathematical analysis for batch size determination. In those cases where the effect of multi-setting or the effect of the sequence in the schedule on the setting costs is low, the computation of the batch-size by selecting a constant setting cost will be little affected, since the setting costs appear under a square root which tends to damp small variations. However, when this effect is appreciable and when it can be determined quantitatively as a function of the number of batches, it is possible to incorporate this function in the existing analysis of batch-size selection. It should be remembered that the formula suggested for fixed setting expense is merely a mathematical model and is applicable in a large number of cases. When reality cannot be described by this model, and when it is no longer justified, there is no reason why the model should not be modified to allow for all the specific factors that play an important role to be included. The universal application of one final formula for every conceivable situation is certainly not to be recommended. Here, again, the conception of the production range is helpful to a certain extent, in that a range of batch-sizes is sought rather than one single quantity, and in many cases a slight variability of setting costs may have little effect on this range.

   The same remarks would apply to Mr. Burbidge's analysis of the variability of storage charges.

4. The two principles suggested by Mr. Burbidge for production control are the principle of balance and the principle of maximum profit (or in my terminology, maximum rate of return). The first question that arises is: are the two principles compatible with each other? The answer is probably the adoption of a system where the supply of the articles to the market or parts to the store is rigidity geared to the production schedule, and I believe that the method of multi-product-scheduling is a first step in this direction. Secondly, even with balance ordering, the logic of which is beyond dispute, some parts can be manufactured in one lot while other parts may be manufactured in several lots. Here the production range is also helpful in determining the number of batches that should be adopted.

   The principle of period batch control is a direct result of the principle of balance, but, here again, the determination of the length of the period and the interbalance of consecutive periods is a question that should be resolved with the aid of multi-product-scheduling. The intuition of production engineers in selecting control periods may have been satisfactory in the past, but I believe that new methods to assist production control can now be developed and employed. Multi-product scheduling is one useful tool. Another may be the use of linear programming for the determination of sequences in product scheduling.

* "Quantities in Batch Production" by S. Eilon. *Engineering, 7th September,* 1956.

** "Economic Lot Sizes in Batch Production" by S. Eilon. *Engineering, 26th October,* 1956.

Mr. Burbidge replies:

THANK you very much for your comments about my Paper. I am glad to see that there is a large measure of agreement between us, and particularly to note that we agree:-

1. that minimum cost does *not* give maximum profit;

2. about the advantages of "balanced ordering" ordering in balanced product sets;

3. that many cost functions are flat in relation to changes in batch quantity.

There are, however, a number of points on which we still disagree, and rather than dispute these points one by one, I would like merely to record certain of my beliefs which you do not appear to share, and to leave the details for discussion later when we meet:-

1. When, in my "Principle of Maximum Profit", I claim that maximum turnover rate gives maximum profit, I am considering the "profit per company per annum" — in other words, the figure which appears (perhaps slightly modified) in the company balance sheet.

2. I believe as a general principle that profit (in my context) can be maximised by maximising the rate of stock-turnover.

3. I am not interested in maximising the profit per batch, because I don't believe that this gives maximum company profits.

4. I believe that cost per piece is mainly a technological function, which can be reduced by improving design, improving production methods, improving buying and increasing output, but cannot be reduced by fiddling with the batch quantity.

5. I believe that cost variation in relation to changes in batch quantity, at constant output rate, is generally insignificant in relation to total cost.

6. I believe that even if there is some increase in cost per batch — and therefore a reduction in the profit per batch — when working at high rates of stock turnover, the reduction in profit is much more than offset by the "opportunity profit" earned on the capital released.

7. I am suspicious of mathematical treatments of this subject, because I have yet to see one in which I could accept the premises, or in which all the significant factors were included.

8. I am not prepared to agree that existing mathematical "models" of this problem give acceptable approximations, because it is impossible to find the margin of error and the solutions are therefore just as much "guesses", as the ones reached by your *bête noir*: the manager's intuition.

9. I suspect that the economic problems associated with Production Control are not susceptible to exact mathematical description, and that they are more a subject for Cybernetics and the "Black Box", than for operational research.

10. I am prepared to accept that simple models, illustrating the relationship between particular functions, have considerable educational value.

11. To me the vital importance of the Operational Research "model" is that it gives an understanding of the law of the system. I believe that the good manager should use his technology, to alter the values of the factors involved, in order to get the best results from the system.

12. I distrust the method of using a "model", in which the existing measured values for all but two of the factors are substituted in the "model" — treating variables as constants — and the equation is then differentiated to find out what the manager should do next.

13. I believe that the minimisation of cost is a technological problem with economic limitations; I do not believe it is an economic problem with technological limitations.

14. I believe that it is the technologist's job to devise methods which will give minimum costs at high rates of stock turnover.

15. I do not believe that it is the economist's job to accept the first "method" that the technologist thinks of, and then try to optimise the situation by finding the most profitable batch quantity to use with it.

16. I believe that "Period Batch Control" and "Standard Batch Control"* are important methods of Production Control, because they make it possible to control low volume, multi-product production, at high rates of stock-turnover.

I know that there is one belief we both share equally strongly—that this question of batch quantity is of vital importance to industry — and I look forward to discussing the subject with you again, on your next visit to England.

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* "Standard Batch Control" by J. L. Burbidge. *Macdonald & Evans, London.*

CORRESPONDENCE TO HEAD OFFICE

There have been quite a number of instances where post intended for Head Office has been delayed, due to the fact that the envelopes have not been clearly addressed, and it may also be assumed that, for the same reason, a number of letters do not reach this office at all.

There are quite a number of places in London which include the name "Chesterfield" in their address, for example, Chesterfield Gardens, W.1., Chesterfield Road, W.4, etc. Delivery of correspondence to Headquarters can only be guaranteed if the envelope, or other package, is accurately addressed. The word "Street" must be written in full, as the abbreviation "St.", when in manuscript is frequently — and understandably — read as "Sq." or "Pl.", and is delivered accordingly with consequent delay. In order to help overcome this problem, it is intended in future, to include the word "Mayfair" in the Institution's address.

Any mail being sent to the Institution must be addressed as follows:-

THE INSTITUTION OF PRODUCTION ENGINEERS,
10 CHESTERFIELD STREET,
MAYFAIR, LONDON, W.1.

Production Engineering Research Association of Great Britain

Quarterly Newsletter to the Institution

MANY leading authorities in the field of production engineering research in many different countries attended the Eighth General Assembly of the International Institution for Production Engineering Research (C.I.R.P.) held in Britain in September. Countries represented included Australia, Belgium, Britain, Czechoslovakia, Finland, France, Germany, Holland, Sweden and Switzerland. This was the first time the Assembly had been held in Britain, previous Assemblies having been held in France, Belgium, Germany, Italy, Holland and Sweden. The intensive programme of scientific sessions, visits to laboratories and factories, and formal receptions for the delegates was arranged by PERA.

At the end of this year's Assembly, Dr. Galloway, Director of PERA, was elected Vice-President of the Institution for the ensuing year, and he will officiate in this capacity at the Ninth General Assembly to be held in Switzerland in 1959.

a common meeting ground

The International Institution for Production Engineering Research was formed in 1949-50, when the four founder members* decided to establish a common meeting ground on which scientists in the field of production technology could discuss their problems freely in an atmosphere of mutual trust and confidence. Production engineering research workers from 14 different countries now report their findings to the Institution, which thus plays an important role in the evolution of improved techniques in many parts of the world. To ensure the highest standards of reporting and discussion, senior membership of the Institution is restricted to not more than four leading authorities in the field of production engineering research in each country. The Institution has for one of its main objectives the removal of barriers to effective communication between production engineering research workers in all parts of the world, and to this end is compiling an international dictionary of production engineering.

During this year's Assembly, a reception and dinner for the delegates and their ladies was arranged by the Institution of Production Engineers at Leamington Spa, the guests being received by Mr. H. Tomlinson, Chairman of the Midlands Region of the Institution. The function was attended by a number of senior members of the Institution. Mr. E.W. Hancock, O.B.E. Past President of the Institution, proposing a toast to C.I.R.P., extended a very cordial welcome to the delegates and their ladies. Mr. Hancock outlined the developments which preceded the establishment of the Institution's Research Department in 1939, and he also referred to the part played by the Institution in the negotiations that took place between the Department of Scientific and Industrial Research and a number of other bodies in 1946 prior to the creation of PERA to undertake research into production techniques on a national scale. (*Mr. Hancock's address was fully reported in the November issue of the Journal.*)

*Dr. D. F. Galloway, Director of PERA.
Ingenieur General P. Nicolau, Director of the I.S.N.C.M. (France).
Professor E. Bickel, Ecole Polytechnique Federale de Zurich (Switzerland).
Professor O. Peters, Universite de Louvain (Belgium).

Some of the leading authorities in the field of production engineering research who attended the 8th General Assembly of the International Institution for Production Engineering Research (C.I.R.P.) photographed during their visit to the Production Engineering Research Association, Melton Mowbray. Left to right are: R. Weill (Belgium); Dr. J. Koloc (Czechoslovakia); M. Czaplicki (Belgium); Professor R. Van Hasselt (Holland); Colonel F. Eugene (France); Professor H. Opitz (Germany); Professor R. Molle (France); behind, J. Simonet (France); Professor E. Kivimaa (Finland); General P. Nicolau (France); Professor H. Wright Baker (Manchester College of Technology); Professor O. Kienzle (Germany); Professor G. Pahlitzsch (Germany); Dr. D. F. Galloway (Director of PERA); Professor P. Landberg (Holland); Professor E. Bickel (Switzerland, President of C.I.R.P.); Mr. N. A. Esserman (Australia); Dr. H. Tornebohm (Sweden); Dr. J. Tlusty (Czechoslovakia); and Mr. J. L. Remmerswaal (Holland).

Professor E. Bickel, President of C.I.R.P., in his response to Mr. Hancock's toast, warmly thanked the Institution of Production Engineers for its generous hospitality and wished the Institution continued success. He said he had been impressed by the great strides made in production engineering in Britain since his last visit some years ago, and congratulated both the Institution of Production Engineers and PERA on the contributions which they had made to the improvement of manufacturing techniques in this country.

The delegates and their ladies were also formally received at the Institution of Mechanical Engineers by the President, Air Marshal Sir Owen Jones and Lady Jones. Sir Lionel Kearns, Chairman of PERA Council and Chairman of H. W. Kearns & Co. Ltd., Broadheath, near Manchester, entertained the delegates to lunch at Prestbury.

During the Assembly, scientific sessions were held in London, Leamington, Melton Mowbray and Buxton, and over 30 papers were presented on recent researches in many fields of production. Subjects discussed included the properties of spark eroded surfaces, a method of measuring machinability, machine tool scales with optical reading devices, testing cemented carbide tools, the performance and wear characteristics of ceramic tools, deep drawing, hydraulic power transmission and its possible application to machine tools, investigating machine tool vibration by means of models, the effect of temperature variations on the accuracy of measurements, residual stress measurement as a means of distinguishing manufacturing methods, and the control of machine tool testing procedures. C.I.R.P. is making arrangements for the publication of all papers in due course, and details will be published when further information is available.

works visits

Visits were also made to the works of A.E.C. Ltd., London, to the Banner Lane Tractor Factory of the Standard Motor Co. Ltd., Coventry, and to the Manchester College of Science and Technology. At A.E.C. Ltd. the delegates and their ladies were received by the Chairman, Sir William Black, and at the Standard Motor Co. Ltd., by the Managing Director, Mr. A. S. Dick.

GROUP PROVIDENT SCHEME

THE Institution has a Provident Scheme for its members in the U.K. The object is to safeguard members against the expense of private treatment for major illnesses, including surgical operations. Private treatment in nursing homes, hospital pay-beds and private specialists' consulting fees, do not come under the National Health Service, and the patient has to pay the full cost. The Provident Scheme is designed to enable members of the Institution, and their dependents, to make the best and speediest arrangements without having to worry about the cost, and to provide a measure of privacy during treatment which is not possible under the National Health Service. Thus the Scheme is not intended to displace the National Health Service, but to provide supplementary benefits.

Under the Institution's Group Provident Scheme, the British United Provident Association's standard rates of subscriptions are reduced by 20% and arrangements are made for the collection of subscriptions annually by Banker's Order made payable to the Institution. Members are entitled to benefit immediately on acceptance and are not subject to the usual three monthly waiting period.

If you are already a private member of the B.U.P.A. and under 65 years of age, you can apply to transfer to the Institution's Group Scheme and get the benefit of 20% reduction in fees. A refund of any balance of your current individual subscription which may be outstanding, would be made.

Members interested in joining this Group Scheme are asked to write to the Secretary of the Institution, asking for full details and an application form.

JOURNAL BINDERS

The increased size of the Journal has made impractical the present type of binder, and as a result of requests from members, the Institution is now able to supply the "Easibind" type of binder, in which metal rods and wires hold the issues in place, and which is designed to hold six Journals.

It will be found that copies of the Journal can be quickly and simply inserted into this binder, without damage to the pages, and that binding six issues at a time, instead of twelve, will facilitate easier reference, and handling of the volumes.

The new binders may be obtained from: The Publications Department, 10 Chesterfield Street, London, W.1, price 10s. 6d. each, including postage. Date transfers, for application to the spine of the binder, can be supplied if required, price 6d. each.

REPORT OF THE

MEETING OF COUNCIL

30th October, 1958

THE second Council Meeting of the 1958 - 1959 Session was held at 10 Chesterfield Street, London, W.1, on Thursday, 30th October, 1958, and was attended by 34 members. The Chairman of Council, Mr. H. W. Bowen, O.B.E., presided at the meeting, at which were present by invitation Mr. D. J. White, Chairman of the Birmingham Graduate Section, and Mr. A. Smith, Honorary Secretary of the Northern Region.

Regional Organisation

It was reported by the Finance and General Purposes Committee that, arising out of discussion at the July, 1958, Council Meeting, an *Ad Hoc* Committee had been set up to examine the Regional Organisation and all other aspects of the proposals contained in the recommendations of the Special Committee on Organisation (The Burke Report). The constitution of the *Ad Hoc* Committee was: Mr. R. H. S. Turner, M.A. (Chairman); the Principal Officers; and one representative from each Region, with power to co-opt. This Committee had held its first meeting the previous day, and Section and Region Honorary Secretaries would very shortly be asked to provide certain information relevant to the Committee's investigations. The Committee would also examine the constitution of the Institution and the Head Office organisations.

Institution Awards

It was also reported that the Institution's Awards Sub-Committee had been reconstituted and was now a Sub-Committee of the Finance and General Purposes Committee. The new terms of reference defined the work of the Sub-Committee as initiating through the Finance and General Purposes Committee (a) Education Awards; (b) Named Papers; and (c) Papers with a Medal Award, and keeping under review the Institution's Awards policy, making recommendations where necessary.

Education

It was reported by the Education Committee, in regard to the Engineering Institutions Examination (Joint Part I) that the Councils of the participating institutions have agreed to the inclusion of The Institution of Production Engineers as one of the bodies conducting the Part I Examination, with a non-continuous representative to the Standing Committee.

The Council were also pleased to learn that in addition to the Production Engineering courses now running at Manchester University, Professor Burstall, of the University of Durham, is launching a first degree honours course.

Elections and Transfers

The Council approved a number of applications for membership and transfer, details of which appear on page 781.

The Journal

It was reported by the Editorial Committee that plans were being made to extend the field of material hitherto considered for publication in the Journal. It was felt, for example, that a number of universities and colleges concerned with production engineering research could undoubtedly supply reports on their activities which would be of interest and value to members of the Institution.

The Journal continued to attract a satisfactory number of advertisements each month, but there could be no relaxation of effort if the sale of advertising space was to be maintained at its present level. Council members were again urged to give the maximum support to the Journal.

Institution Papers

The Papers Committee reported that arrangements had now been completed for the 1958 George Bray Memorial Lecture, which would be presented in London on 29th April, 1959. The speaker would be a Director of J. Lyons Ltd., who would take as his subject food processing, with particular reference to work study and production problems.

With regard to the 1959 Viscount Nuffield Paper, this was to be presented in Glasgow in the autumn of next year by Dr. C. Timms, of the Mechanical Engineering Research Laboratories. Dr. Timms would speak on recent developments in spur and helical gears.

Research

The following reports were made on behalf of the Research Committee:

Materials Handling Group. The Convention held at Brighton was regarded as most useful by those

attending and attracted considerable publicity. At a special meeting prior to the opening of the Convention, Section representatives were able to discuss their problems and experiences.

Materials Utilisation. The draft of the Sub-Committee's report was now in the hands of the printer.

Sources of Information Directory. One section remains to be completed by the Chairman of the Sub-Committee.

Control of Quality. The Sub-Committee's Report on "Quality — Its Creation and Control" had attracted widespread publicity.

The future activities of the Research Committee include work on the following subjects :-

(a) Co-ordination of Production Management Techniques;
(b) Electronics and Kindred Modern Developments as Applied to Process Loading;
(c) History and Modern Day Functions of the Production Engineer.

Standardisation

It was reported by the Standards Committee that the new Sub-Committee on International Standards, under the Chairmanship of Mr. T. A. C. Sparling, had now been formed and had held its initial meeting.

The Standards Committee continues its work of appointing representatives to serve on B.S.I. Technical Committees. At the present time, 80 members are serving as representatives of the Institution on 130 B.S.I. Committees. The Committee is also in active liaison with the National Joint Committee on Non-Destructive Testing; the British Institute of Management; and the British Productivity Council.

The Library

It was reported by the Library Committee that there had been a slight decrease in enquiries during the summer months. A bibliography of literature on Materials Handling had been compiled for the Materials Handling Group, and was now on general sale.

Sections outside the United Kingdom

Mr. R. H. S. Turner, Vice-Chairman of Council, reported that a number of overseas members had visited Headquarters since the last Council Meeting. Mr. Goodchild had continued his discussions with the Secretary on the position of the Institution in India, and the hope had been expressed that in the not-too-distant future, a representative of Headquarters would visit India.

Mr. J. M. Steer, Chairman of the Australian Council, had written referring to the very welcome visit of Mr. Harold Burke, which had done a great deal to clear up a number of problems and to strengthen the relationship between London and Australia. Mr. Turner suggested that Council should put on records its appreciation of Mr. Burke's activities in Australia in support of the Institution, and this was unanimously agreed.

Honours

The Council was pleased to learn that Her Majesty the Queen had conferred the award of M.B.E. upon Mr. A. S. Downes, Associate Member, of Wolverhampton.

Region and Section Reports

The Council received a number of reports from Regions and Sections, extracts from which will appear in the January Journal.

Obituary

The Council recorded with deep regret the deaths of the following members :-

T. W. Chick; A. E. Eggington; H. G. Hilton; E. G. R. Kipps; P. H. Muirhead.

Date and Place of Next Meeting

It was agreed that the next meeting of the Council would take place on Thursday, 29th January, 1959, at 11 a.m., and that the Annual General Meeting should be held at 2 p.m. on the same date.

ELECTIONS AND TRANSFERS — continued

SYDNEY SECTION

As Associate Members
J. S. French; G. E. Owen.
Transfers
From Graduate to Associate Member
D. M. Hallam.
From Students to Graduates
W. W. Leal; R. M. Croucher.

TEES-SIDE SECTION

As Associate Member
I. Davies.
As Graduate
D. K. Hiro.
Transfer
From Graduate to Associate Member
T. Young.

WESTERN SECTION

As Associate Member
H. Williams.
As Graduates
R. H. Lowres; E. R. Cutler; J. K. Foden.
As Student
G. C. Straughen.

WOLVERHAMPTON SECTION

As Member
G. N. Skidmore.
As Graduates
W. R. Moule; R. Benion; J. L. Freeman.
As Students
B. Bramhill; R. S. Evans.
Transfers
From Graduates to Associate Members
G. Rogers; R. E. J. Roberts; B. A. Jones; R. C. Briggs; A. W. Guest.
From Students to Graduates
W. Perry; K. J. Roberts.

WORCESTER SECTION

As Associate Member
G. H. Robinson.
As Graduate
G. E. Blundell.

NO SECTION

As Associate Members
J. C. Bihl; M. A. Wahid.
As Graduates
B. K. Joshi; Z. Ali.
As Student
M. E. W. Dassanayake.
Transfers
From Associate Member to Member
S. Eilon.
From Student to Graduate
S. M. Chandaria.

ELECTIONS AND TRANSFERS

30th October, 1958

BIRMINGHAM SECTION
As Associate Members
V. E. Shute; G. Baker.
As Graduates
B. W. Jabbitt; D. S. Myring; F. E. Newton; J. E. Watkins; K. N. Matthews.
As Student
J. Lovatt
Transfer
From Student to Graduate
F. Ireland.

BOMBAY SECTION
As Associate Members
S. D. Amin; K. R. Rao.
As Graduates
C. V. Doshi; P. A. Shah; A. K. De.
As Students
A. D. Narang; S. S. Hariharan; N. K. Kar; I. C. Pandey; V. R. Gopisetty; M. N. Hoda; B. K. Pawagi; B. C. Bhattacharya; A. D. Patel; M. N. Kamath; P. C. Thomas; D. P. Ghoshal; R. Venkataramani.
Transfer
From Graduate to Associate Member
B. N. Ganguly.

CALCUTTA SECTION
As Graduates
A. K. Bhattacharya; O. S. Chaudhry; N. S. Batlaw; A. M. Menda; V. S. Varma; C. K. Malhan.

CANADA SECTION
Transfer
From Student to Associate Member
F. D. Hall.

CARDIFF SECTION
As Associate Member
F. W. J. Randall.

COVENTRY SECTION
As Graduate
A. B. Taylor.
Transfer
From Graduate to Associate Member
F. L. Twigg.

DERBY SECTION
As Graduates
E. J. Farrell; W. Smith.

DONCASTER SECTION
As Student
H. B. Pearson.
Transfer
From Associate Member to Member
G. L. A. Draper.

DUNDEE SECTION
Transfers
From Graduates to Associate Members
K. Bird; J. Bell
From Students to Graduates
D. M. P. Scott; J. W. Anderson.

GLASGOW SECTION
As Graduate
W. G. S. Guthrie.
As Student
J. Reid.
Transfers
From Graduates to Associate Members
J. H. Morrison; D. M. Murray.

GLOUCESTER SECTION
As Member
R. W. Walker.
As Graduate
L. Powell.
As Student
P. J. Pratley.
Transfers
From Associate Member to Member
A. J. Pack.
From Graduates to Associate Members
T. Tanner; J. I. Dennison.

LEICESTER SECTION
As Associate Member
A. W. Plent.
As Associate
C. Spector.
As Graduates
C. H. Wright; G. Fox.
Transfers
From Graduate to Associate Member
A. C. Evans.
From Student to Graduate
E. R. Heggs.

LINCOLN SECTION
As Associate Member
H. Proffitt.
Transfers
From Associate Member to Member
A. L. Martin.
From Graduate to Associate Member
C. K. Pickles.

LIVERPOOL SECTION
As Students
B. Stevens; D. C. Williams
Transfers
From Students to Graduates
S. D. Allanson; A. Gibson.

LONDON SECTION
As Associate Members
G. T. Jeffries; H. Berkovi; A. Ringshaw; R. A. Staker; D. R. Harper; E. Adnams; P. G. Hillier; E. A. Cartner; J. Burton; L. B. Whittaker.
As Graduates
A. G. Nunn; H. W. Jones; M. L. Howell; P. J. Jenkins; D. C. Parris; L. R. Rust; D. Yardy; R. L. Varma; L. A. Whitehead; D. S. Anker; L. J. Stannett; I. T. Bristow; K. L. Grigg; M. S. Scott; F. G. Goodwin.
As Students
A. H. Meadows; P. J. Kenton; T. J. Kelly; B. M. Darroch, J. C. Forward; J. R. Smith; F. W. Godenzie; C. J. Steele.
Transfers
From Associate Member to Member
M. Rivlin.
From Graduates to Associate Members
C. L. Wright; R. S. Ritchie; M. A. Nagle; V. F. Burgess.
From Students to Graduates
P. W. Wilkes; R. S. Grant; B. E. Collier; N. S. Gay; J. F. Reeves.

LUTON SECTION
As Associate Member
T. N. Gillbe.
As Graduates
P. A. T. Arrigoni; R. J. Caddy; M. Jackson.
As Students
B. J. Smith; R. R. Wiltshire; B. R. Mills.

MANCHESTER SECTION
As Associate Member
T. B. Stamp.
As Graduates
J. Fray; R. Collinge.
As Students
D. B. Richardson; M. D. Robinson.
Transfers
From Graduate to Associate Member
K. McConnell.
From Student to Graduate
W. Lord.

MELBOURNE SECTION
As Associate Member
B. F. Einsiedel.
As Graduate
E. P. H. James.
As Student
I. D. Jowett.

NOTTINGHAM SECTION
As Member
J. Broadhurst.

NORTHERN IRELAND SECTION
As Graduate
F. D. Duffin.

NEWCASTLE UPON TYNE SECTION
Transfer
From Graduate to Associate Member
E. Stephenson.

OXFORD SECTION
As Associate Member
J. W. Gibbard.
As Associate
B. A. Di Mascio.
As Graduate
A. H. Cree.
As Student
A. D. Tomkinson.
Transfers
From Graduates to Associate Members
G. J. Bullock; N. H. W. Ward.

PRESTON SECTION
As Graduates
J. E. Reid; A. Williams; J. Crossley; G. Rostron.
As Student
B. Taylor.
Transfers
From Graduate to Associate Member
G. H. Farnworth.
From Students to Graduates
P T. Hughes; A. M. Marshall.

READING SECTION
Transfers
From Students to Graduates
P. H. Reynolds; R. Peake; R. H. Philipson.

ROCHESTER SECTION
As Graduate
M. J. Chamberlain.
As Student
R. J. Spain.
Transfer
From Student to Graduate
E. W. Munn.

SOUTH AFRICA SECTION
As Member
L. D. Evans
As Associate Member
R.Young
New Affiliated Firm
C. E. Hultquist (Pty.) Ltd.

SOUTH ESSEX SECTION
As Associate Member
E. Forster.
As Graduates
C. Drinkwater; K. K. Nohria.
Transfer
From Graduate to Associate Member
R. T. Marshall.

SHEFFIELD SECTION
As Associate
R. S. Gander.
Transfer
From Graduate to Associate Member
R. W. Hammond.

SHREWSBURY SECTION
As Graduate
H. D. Mainwaring.

SOUTHAMPTON SECTION
As Graduates
D. Brown; I. R. Hooper; A. G. Cozens.
Transfers
From Students to Graduates
N. Duffield; F. K. J. Coombs.

STOKE-ON-TRENT SECTION
As Graduate
F. J. Bentley.
Transfer
From Student to Graduate
D. Wood.

SWANSEA SECTION
As Associate Member
A. J. Bannister.
As Graduate
R. J. Parkin.

(concluded on facing page)

INCOME TAX RELIEF ON MEMBERSHIP SUBSCRIPTIONS

Under the provision of the Finance Act, 1959, professional membership subscriptions are allowable for relief of Income Tax, where the professional society is approved under the Act.

The Commissioners of Inland Revenue have approved The Institution of Production Engineers for the purpose of Section 16, Finance Act, 1958. This means that the whole of the annual membership subscription paid by a member from his own private income will be allowable as a deduction from his emoluments, assessable to Income Tax under Schedule E.

The following will not qualify for relief of tax :-

(a) members whose subscriptions are paid by their employer, or other body;

(b) members who have signed a Deed of Covenant with the Institution. On expiry of the Covenant period, these members will be able to obtain relief of tax, referred to above.

Members of the Institution who consider themselves entitled to the relief should apply to their local tax office, as soon as possible, for Form P.358, on which to make a claim for adjustment of their P.A.Y.E. coding.

MEMBERS' INDEX

During last summer all members of the Institution in the United Kingdom were sent a questionnaire in the form of an index card, which they were asked to complete and return to Head Office. The response has been good, but there are still quite a number of members who have not returned the card. These members are asked to do so as early as possible as this accumulated information is invaluable, both to Head Office and to the working of the Institution.

When returning the card, many members offer their services to the Institution in one form or another, such as presenting Papers to local Sections and serving on Committees. This help is greatly appreciated, but it is not possible for all offers to be taken up immediately, and the Secretary will approach members when need arises.

In order that the new index may be kept up to date, all members are urged to notify Head Office immediately any changes occur, particularly changes of address or changes of appointment.

NEWS OF MEMBERS

Mr. John Mitford Brice, Member, Technical and Commercial Manager of The Rockwell Machine Tool Company, Ltd., has been appointed a Divisional Director of the Company. Mr. Brice is the immediate Past Chairman of the Institution's Editorial Committee, and a serving member of the Finance & General Purposes Committee, and of the Papers Committee.

Mr. R. W. Brocklehurst, Member, Superintendent of The English Steel Forge & Engineering Corporation Ltd., has been appointed to the board of that company.

Mr. H. A. Chambers, Member, General Manager of The Rockwell Machine Tool Company, has been appointed a Divisional Director of the Company.

Mr. L. R. Evans, Member, Superintendent of the Grimesthorpe Works of The English Steel Castings Corporation Ltd., has been appointed to the board of that company. He is a Member of Council and of the Sheffield Section Committee. Mr. Evans is also a Corresponding Member of the Papers Committee.

Mr. R. Fielding, Member, Superintendent of The English Steel Spring Corporation Limited, has been appointed to the board of that company.

Mr. R. Turner Hood, Member, has been appointed Managing Director of Brades & Nash Tyzack Industries Ltd., and also appointed a Director of Brades & Nash Tyzack Industries of Canada Ltd.

Mr. G. P. Darnley, Member, has been appointed Joint Managing Director of Bratby & Hinchliffe Limited, Manchester.

Mr. W. W. Jeacock, Member, General Manager of The Coventry Gauge & Tool Company, Ltd., has been appointed a Divisional Director of the Company. Mr. Jeacock serves on the Coventry Section Committee.

Mr. A. J. Lund, Member, has recently been appointed Director of Amalgamations (Private) Limited, Madras. Mr. Lund retains his position as Director & General Manager of Simpson & Company Ltd., Madras.

Mr. C. W. Mustill, Member, is now Managing Director of Jackson Boilers Ltd., of Leeds. He was President of the Yorkshire Section of the Institution from 1941 - 1944. Mr. Mustill served on the Management Committee of the Institution's Research Department from 1943-1946 and also as an additional Section Representative on Council. He was a member of the Yorkshire Section Committee for 14 years.

Mr. G. S. Cope, Associate Member, has been appointed General Manager of Freeman, Taylor Machines Ltd. He joined the firm three years ago, and will be responsible for sales and production.

Mr. S. Billington, Associate Member, has now taken up a position as Plant Engineer to The Jardine Dyeing & Finishing Co. Ltd., Hong Kong. Mr. Billington was formerly Chief Engineer to the Compania America Fabril, Brasil.

Mr. P. Vince Brown, Associate Member, has been transferred by the Ministry of Supply to the Aircraft and Armament Experimental Establishment at Boscombe Down, where he will be attached to the Aircraft Engineering Division. He was previously in the Aircraft Production Development Branch at St. Giles Court, London.

Mr. E. H. Mather, Associate Member, has taken up a new appointment recently with Withers Limestone Ltd., Carnforth, as Group Engineer.

Mr. L. B. Rutter, Associate Member, has recently taken up the position of Works Manager with Birfield Tools Ltd., Wyken, Coventry.

Mr. R. P. Shaw, Associate Member, of Thomas Bolton & Sons Ltd., Froghall, Stoke-on-Trent, is joint holder of the 1958 Sir Alexander Roger Travelling Scholarship, awarded annually to employees of the British Insulated Callender's Cables group of companies. Mr. Shaw will spend several months in the Spring of next year visiting copper and copper alloy producers in the United States.

Mr. M. E. Clark, Graduate, is at present with the Atomic Weapons Research Establishment, Aldermaston, Berkshire, on secondment from the Ministry of Supply.

Mr. F. B. Leak, Graduate, has now been appointed Plant Engineer with Walker Brothers (Wigan) Limited, where he was formerly Assistant Plant Engineer.

DIARY DATES FOR 1959

March 11th ... ... **The 1958 Viscount Nuffield Paper,** to be presented at the University of Birmingham.

Speaker: **Dr. N. P. Inglis,** Metals Division Research Director, Imperial Chemical Industries Limited.

Subject: **"The Production, Fabrication, Properties and Uses of Some of the Newer Metals."**

April 16th/17th ... **The Seventh Aircraft Production Conference, Southampton.** (See Supplement to this Journal.)

April 29th ... ... **The 1958 George Bray Memorial Lecture,** to be presented in London.

Subject: **"Food Production with Particular Regard to Work Study Methods and Production Problems."**

October 12th ... ... **The 1959 E. W. Hancock Paper,** to be presented in Bristol.

Subject: **"Human Relations in Industry."**

Speaker: **Mr. R. A. Banks,** Personnel Director, Imperial Chemical Industries Limited.

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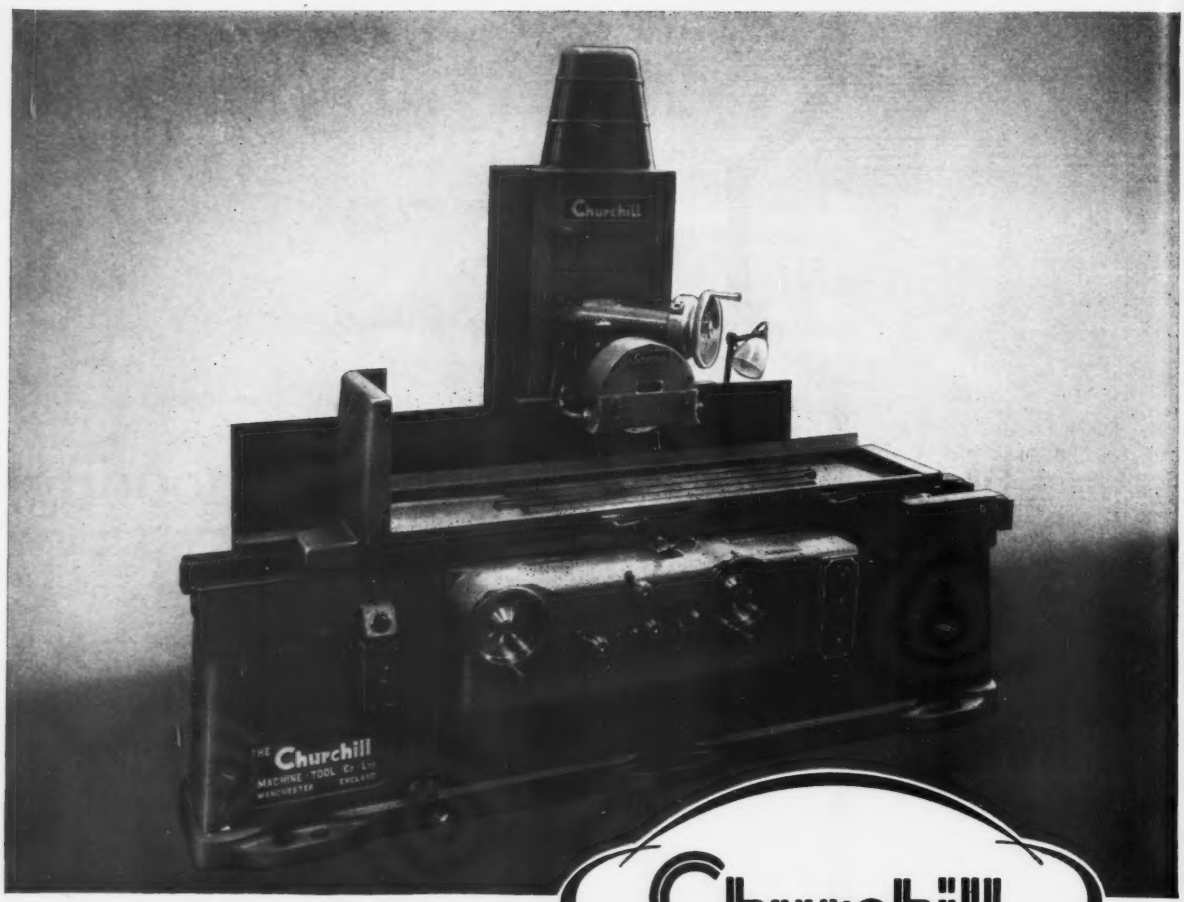

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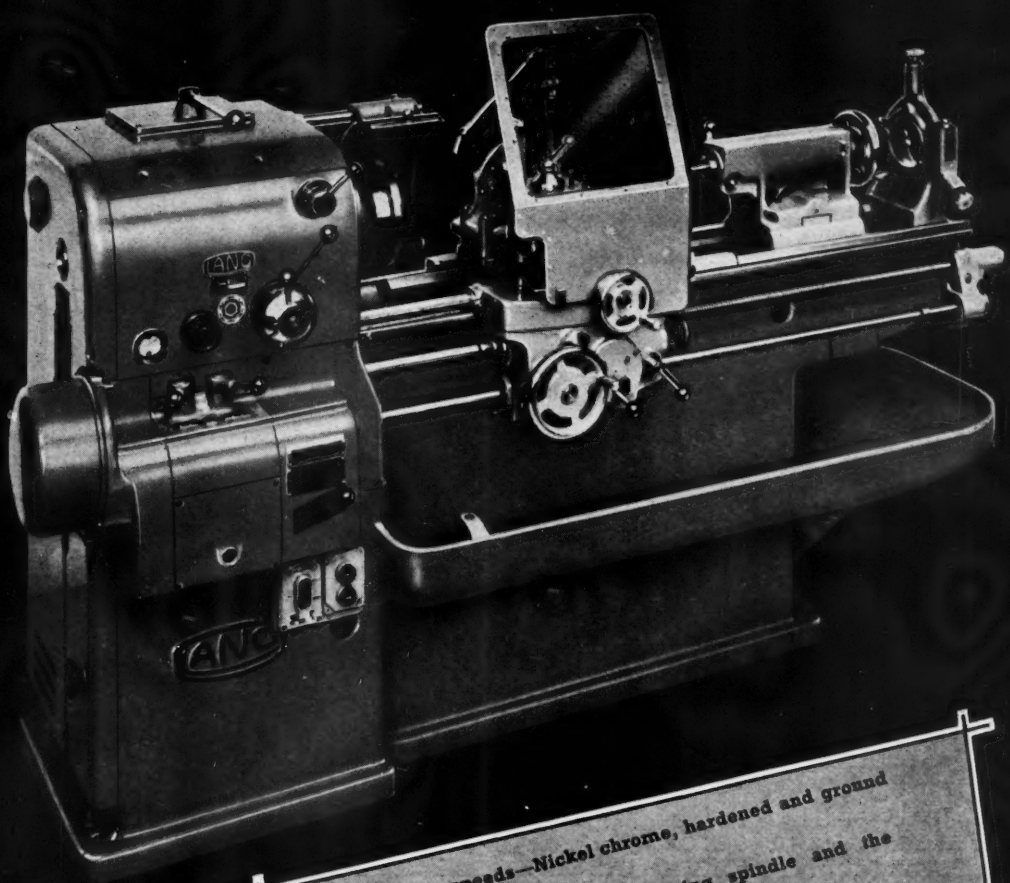

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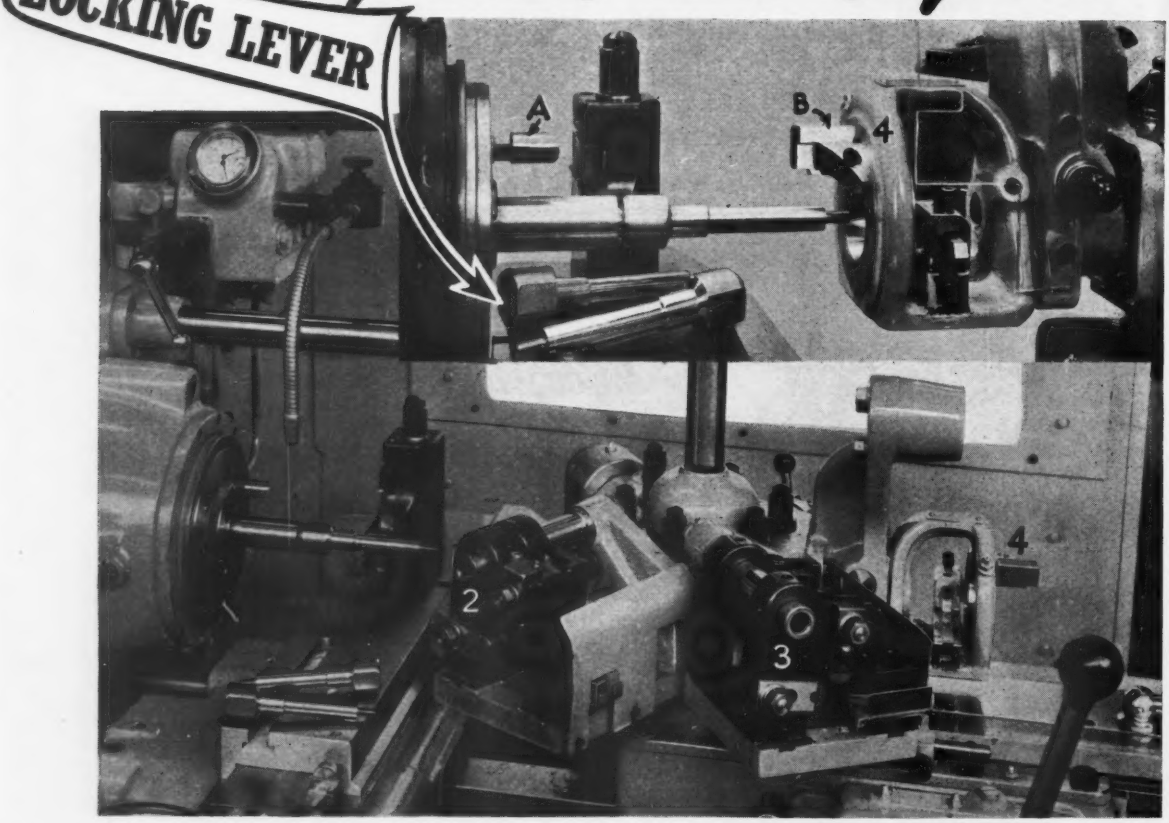

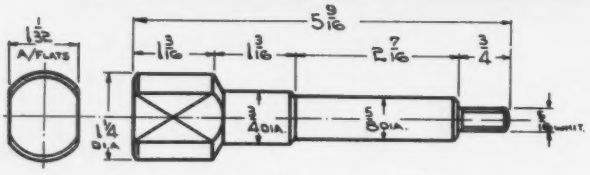

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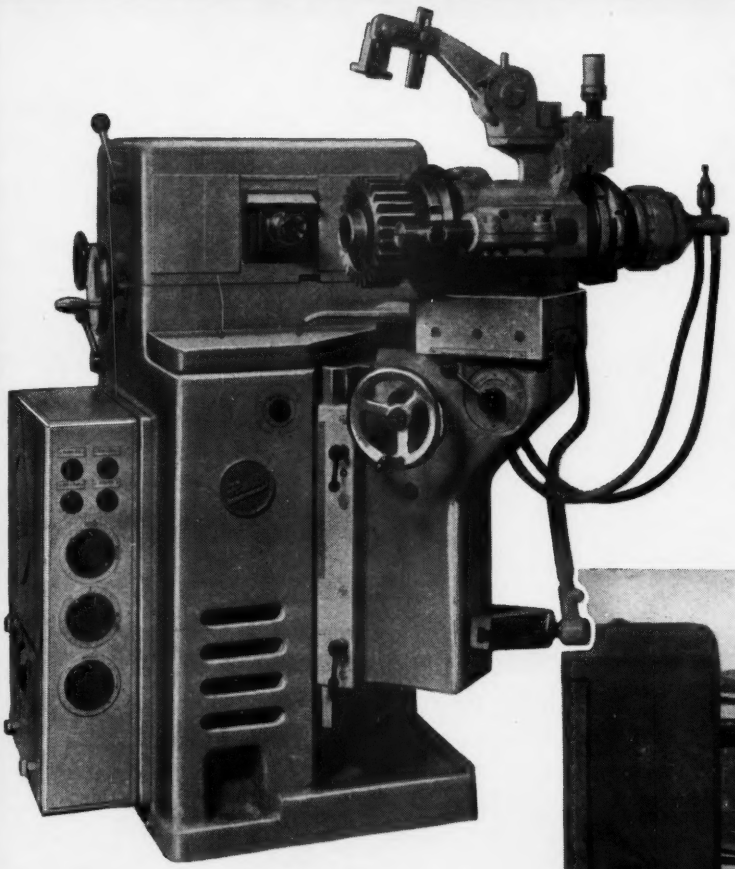

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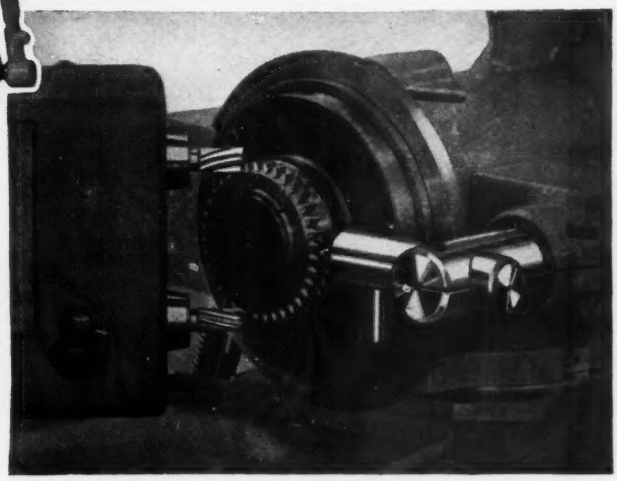

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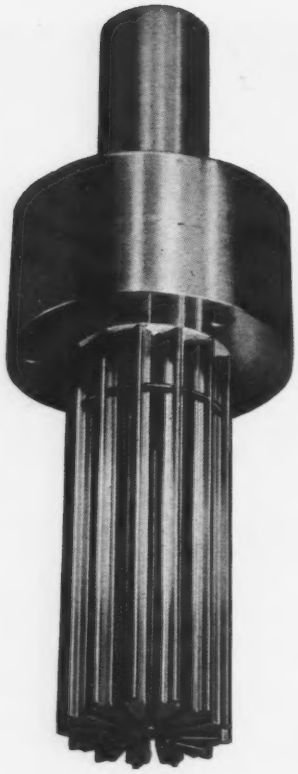
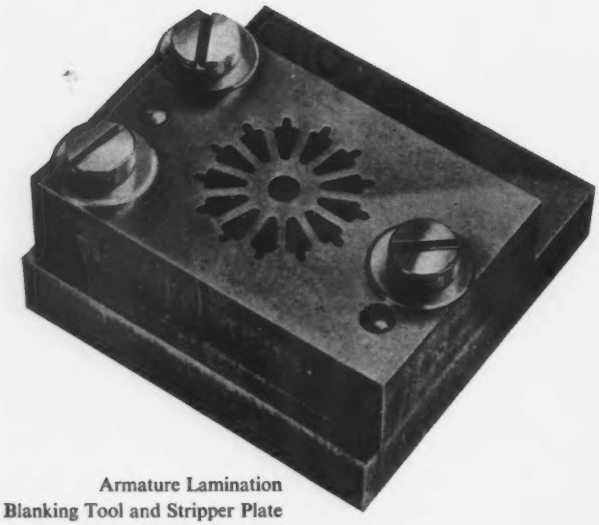
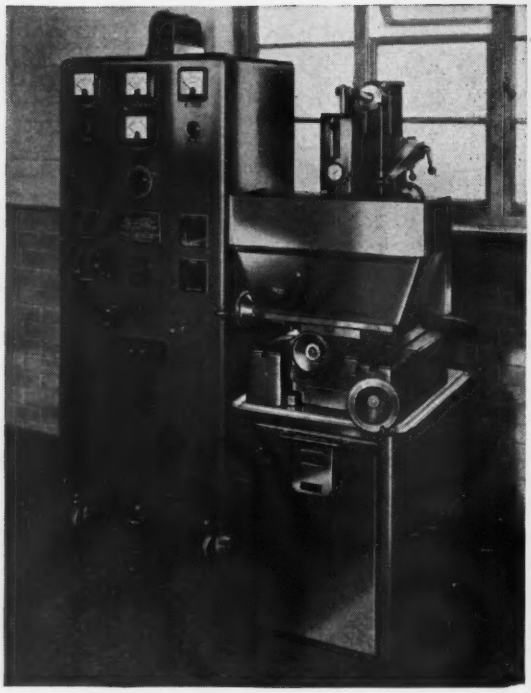


SPARK MACHINED from the SOLID



Armature Lamination
Blanking Tool and Stripper Plate



SPARCATRON MARK III
MODEL INCORPORATING THE
LATEST IMPROVEMENTS

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IMPREGNATED DIAMOND PRODUCTS LTD · OF GLOUCESTER · ENGLAND

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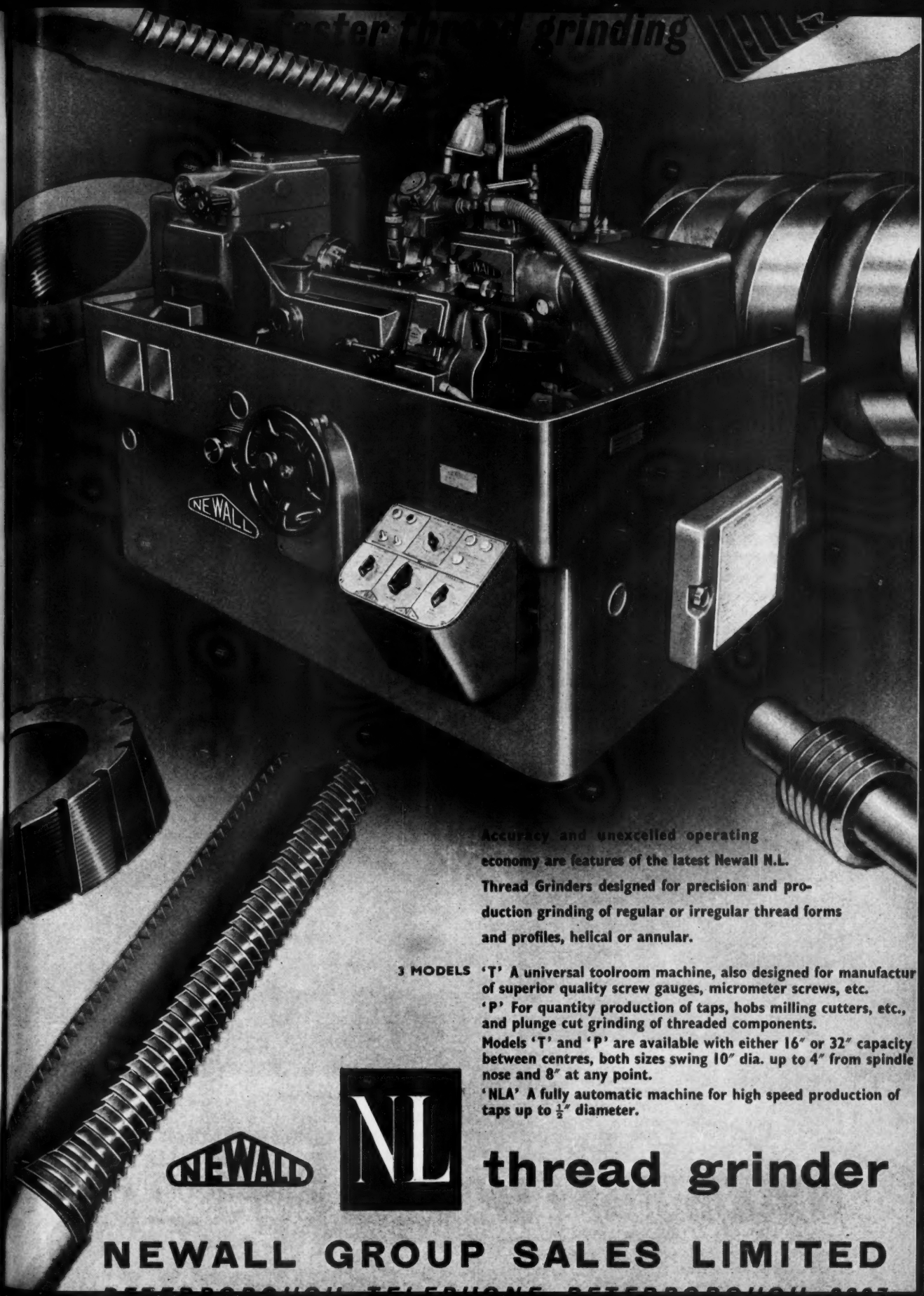
BURTON GRIFFITHS & CO LTD · KITTS GREEN · BIRMINGHAM 33



Accuracy and unexcelled operating economy are features of the latest Newall N.L. Thread Grinders designed for precision and production grinding of regular or irregular thread forms and profiles, helical or annular.

3 MODELS

'T' A universal toolroom machine, also designed for manufactur of superior quality screw gauges, micrometer screws, etc.

'P' For quantity production of taps, hobs milling cutters, etc., and plunge cut grinding of threaded components.

Models 'T' and 'P' are available with either 16″ or 32″ capacity between centres, both sizes swing 10″ dia. up to 4″ from spindle nose and 8″ at any point.

'NLA' A fully automatic machine for high speed production of taps up to $\frac{1}{2}$″ diameter.

NEWALL NL thread grinder

NEWALL GROUP SALES LIMITED

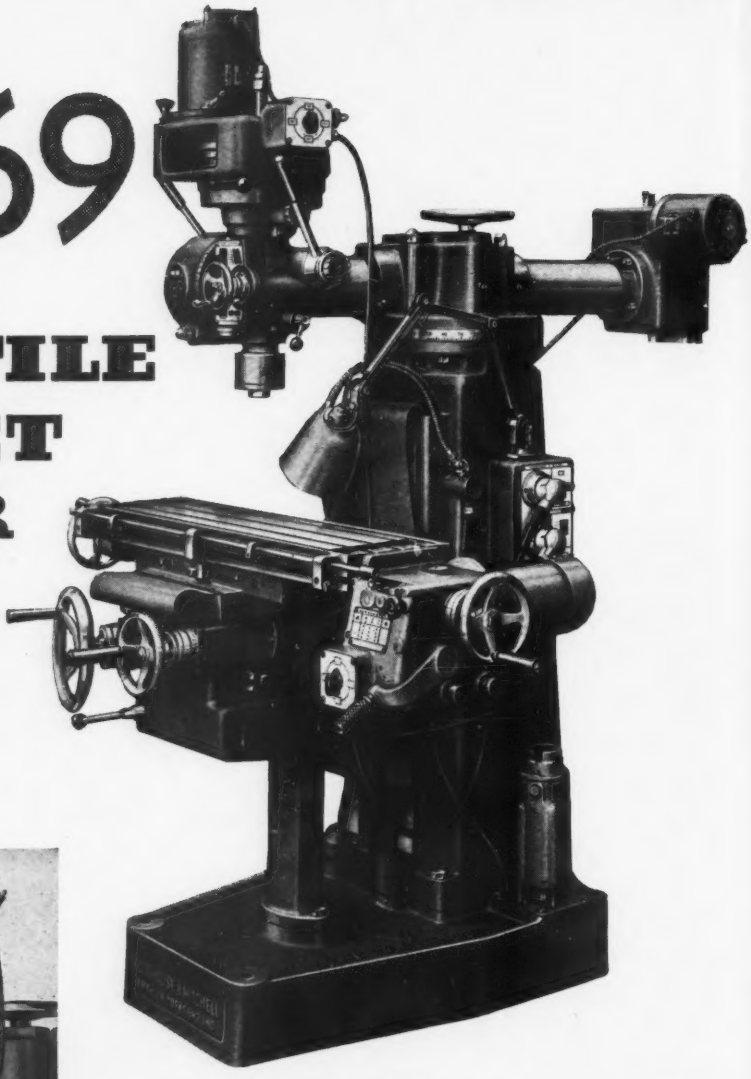
PETERBOROUGH TELEPHONE PETERBOROUGH

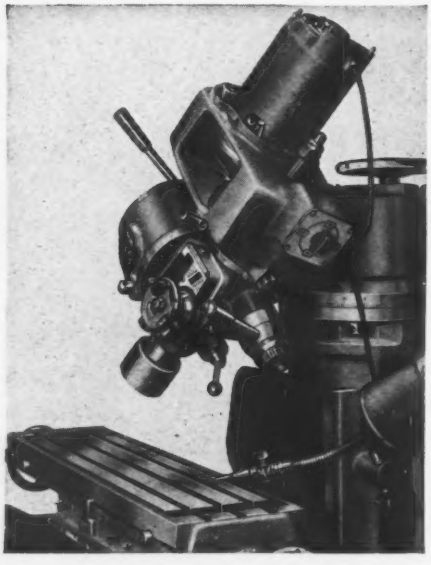
wm 369

The

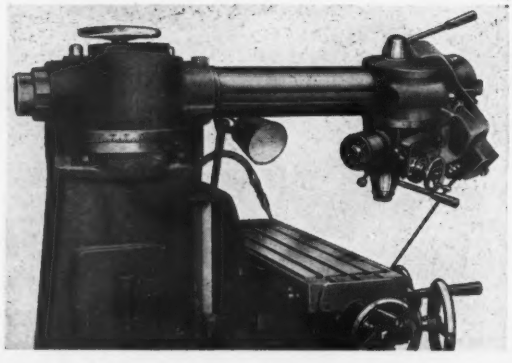
VERSATILE TURRET MILLER

for Milling, Boring, and Jig Boring at any angle, Keyway and End Milling, Die Sinking, Mould and Pattern Making. Machine illustrated is fitted with table power feed and slotting head as extras.





Head swivelled and tilted.



Head angled, swivelled and tilted.

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WAKEFIELD ROAD
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PHONE:— BRIGHOUSE 627 (3 LINES)
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WM.86

Electrical Aids in Industry *Data Sheet* **No. 2**

Induction Heating-1

Electro-magnetic induction was discovered by Faraday and used by him to evolve the electric motor. In some cases, induction can be a nuisance by causing heat losses to arise from induced eddy currents in nearby pieces of metal, but in industry today those heat losses are being turned to good account as a method of metal heating.

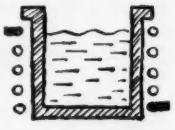
Induction heating produces heat only in the work piece. This is a fascinating and spectacular process which has the additional merit of being extremely effective. An important feature of induction heating is that it gives rapid temperature rise with no time lag, starting being instantaneous. Perhaps its greatest advantages are that it can be used in automatic processes and does not demand skilled labour.

Induction heating can deal efficiently with all the applications outlined below, and including metal melting, preheating and stress relieving, surface hardening, heating of large components, preheating of steel tubes for manipulating, heating for shrinking, for forging and extrusion, as well as for the heating of vessels. There are various methods of applying it, the method to be used being dictated by the application.

Technical details relating to the choice and use of individual types of induction heating will be set out in a subsequent data sheet.

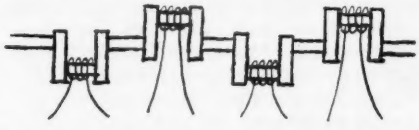
Metal melting

The oldest and largest application of induction heating lies in the melting of metals. The outstanding advantages are: freedom from deleterious gases and products of combustion and other contaminants, rapid speed of melting, low running costs, improved working conditions and reduced metal loss.



Metallurgical processes

This covers a large variety of processes which may be basically divided into surface heating and through heating. Most processes fall into the former category and are used for the purpose of



skin hardening. They include the treatment of such components as: pins, camshafts, crankshafts, rollers, cylinder liners, gear teeth, rocker arms and shafts and valve stems.

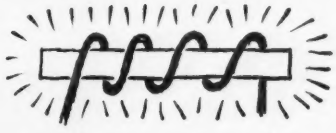
5857

Through Heating

When the current in an induction coil is maintained for a longer period it results in the heat engendered in the work piece penetrating to a greater depth and eventually throughout the piece. It is largely used for the heating of slugs and billets, for upsetting and upset forging, flanging and nosing, shearing and forging and bolt blanks for heading.

Annealing

Induction heating is the ideal method of altering the character of metals for a special purpose. Annealing and its related process of tempering, normalising and stress relieving are prominent in



this category. In the case of annealing, one feature of the treatment is that it can be localised, while induction tempering can do in one minute what would require half-an-hour or more with conventional furnace heating.

Brazing, soldering and welding

Brazing and soldering by induction are the quickest and cleanest methods of joining metals together, and it is often beneficial to re-design the parts so that the fullest advantage can be taken of induction heating. Brazing can be used in the case of: carbide inserts for tools, tips for rock drills, parts for universal joints, etc., while the many applications of soldering are well-known. It was not until well into the present century that the age-old craft of welding became a positive aid to greater productivity. Induction welding produces a good, clean weld because oxidation is almost absent.

Miscellaneous Application

Induction heating can be profitably used for a large variety of purposes, including the fusion and hot pressing of powders, heating *in vacuo*, gas determination in metals, fusion of glass, chemical work and many other processes.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association.

Excellent reference books are available on electricity and productivity (8/6 each or 9/- post free)—"Induction and Dielectric Heating" is an example.

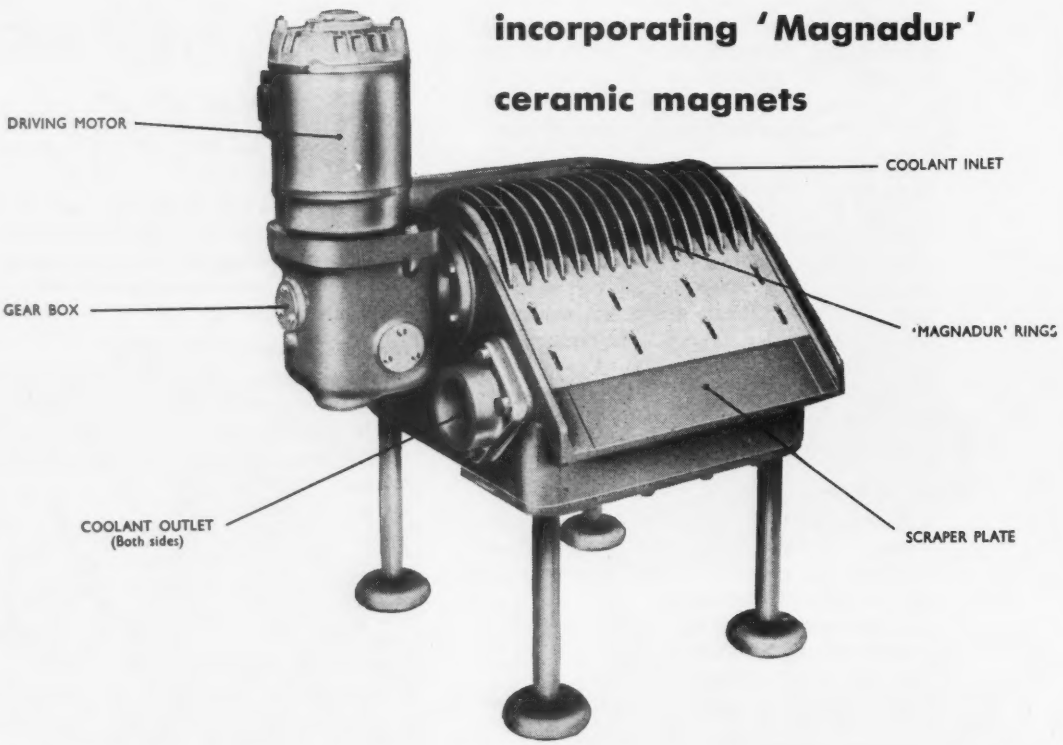
E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

Issued by the Electrical Development Association, 2 Savoy Hill, London, W.C.2.

Increase production with NEW

PHILIPS 'Magna-Drum' COOLANT CLARIFIER

incorporating 'Magnadur' ceramic magnets



- *Higher Production rates*
- *Finish improved.*
- *Completely automatic.*
- *Fewer wheel dressings*
- *Coolant saved*
- *Sludging of settling tanks prevented*

The heart of the New Philips 'Magna-Drum' coolant Clarifier is a compact unit which is magnetic over its whole surface area, and incorporates 'Magnadur' high power ceramic magnets. The equipment will filter straight cutting oils or soluble oil coolants without any modification. A very high proportion of grinding abrasive is always entrained in the ferrous swarf collected. Standard 'Magna-Drum' Clarifiers are available for handling flows of 300 g.p.h. to 7,500 g.p.h. British Patent No. 765495.

Larger equipments can be designed to suit special applications.

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PRECIMAX

for Angular grinding

PRECIMAX MPH

ANGULAR HEAD MACHINE

GRINDING CAMSHAFTS AT THE ROVER CO. LTD.

For form grinding shoulders and flanges on these camshafts, the Rover Company use the PRECIMAX angular system, which is unsurpassed in its combination of accuracy and speed of production. The machine shown is the PRECIMAX MPH.10/24/45/90 Cylindrical Grinding Machine, one of a complete series of angular head machines which embody such valuable features as the combined hydraulic tailstock and wheel truing device. Models are available with alternative wheelhead angles of 30 deg. and 45 deg., and with direct or oblique wheelhead approach. Full details of the entire range are available on request.

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PROPERTIES of DMC MOULDINGS

EXCELLENT MECHANICAL STRENGTH
HIGH IMPACT STRENGTH
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TEMPERATURE RESISTANCE
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DMC* mouldings

(POLYESTER/GLASS FIBRE)

for high mechanical and electrical strength at economical cost

All the mechanical/electrical advantages of polyester/glass fibre are yours to exploit—with the added virtue of economy. *Dough Moulding Compound is the new material that speeds and simplifies moulding because it needs only low pressures and short cure times in conventional compression presses. The proportions of resin, fibre and filler can be varied to emphasise desired properties, according to applicational need, or for cost advantages. STREETLY technicians have thoroughly investigated the characteristics and mould behaviour of all the reasonable permutations of this versatile material; production runs have provided first-hand practical experience. We are therefore in an unrivalled position to supply large numbers of DMC mouldings, produced in automatically controlled BIPEL presses with the exactitude for which STREETLY is so well-known.

Kelvinator refrigerator door latch moulding. DMC material imparts high mechanical strength throughout and excellent resistance to extremes of temperature. Moulded by the Streetly Manufacturing Co. Ltd., for Kelvinator Limited, Crewe.

ESTABLISHED APPLICATIONS

Transport

Car and bus heater housings, air ducts, fan blades, seat bases and sides, armrest foundations, door panels, window strips

Electrical

Stand-off insulators, coil forms, brush holder insulators, support blocks, switch boxes and covers, circuit breaker bases, battery housings

Domestic

Washing machine impellers, spin dryers, refrigerator parts, suction cleaner parts, furniture handles, door handles, sports goods

DMC for strength—**STREETLY** for **DMC** mouldings

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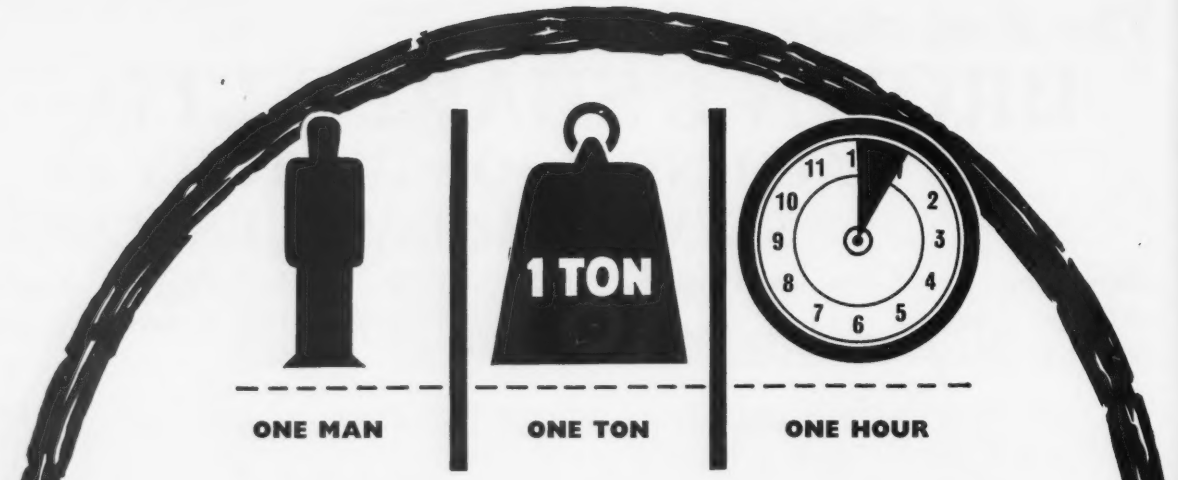

A formula for efficient and economical Blast Cleaning.

The Centriblast Airless Rotary Barrel is still unsurpassed for speed and economy in cleaning all types of castings, forgings and fabrications within the limit of its capacity.

May we send you details of our full range of Compressed Air Operated and Airless Blast Cleaning Plant?

CENTRIBLAST

36 in. x 42 in. Airless Rotary Barrel Shot Blast Machine.

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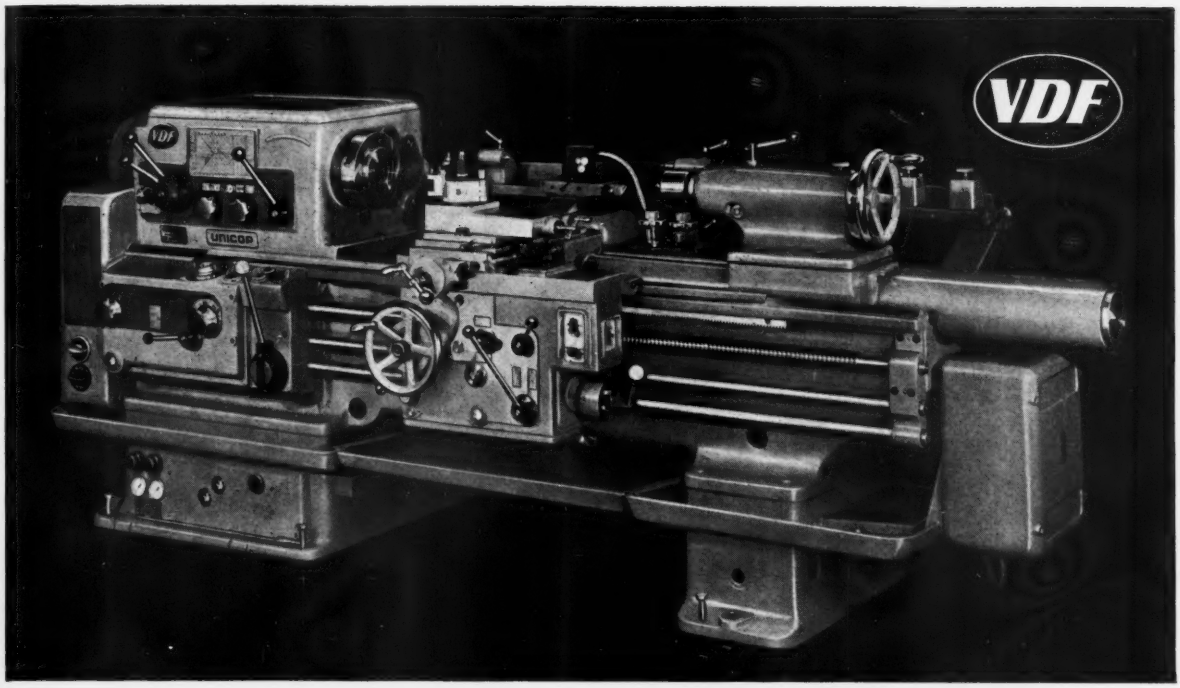


Ultra Sensitive Multi-Purpose VDF Unicop I Copying Lathe

- So sensitive it can produce a sphere.
- Ideal for workshops where a single-purpose copying lathe would be uneconomical.
- For normal and copy turning.
- Suitable for longitudinal, external and internal copying and face copying.
- Electronic-hydraulic.
- Copying traverse up to 29½" and cross copying to 5". Increased if required.
- Can be delivered with high-speed headstock (top speed up to 5,600 r.p.m.).
- Also available Unicop III for production copying and Unicop V giving greater capacity for shaft work.

BRIEF SPECIFICATION
(3 models available)

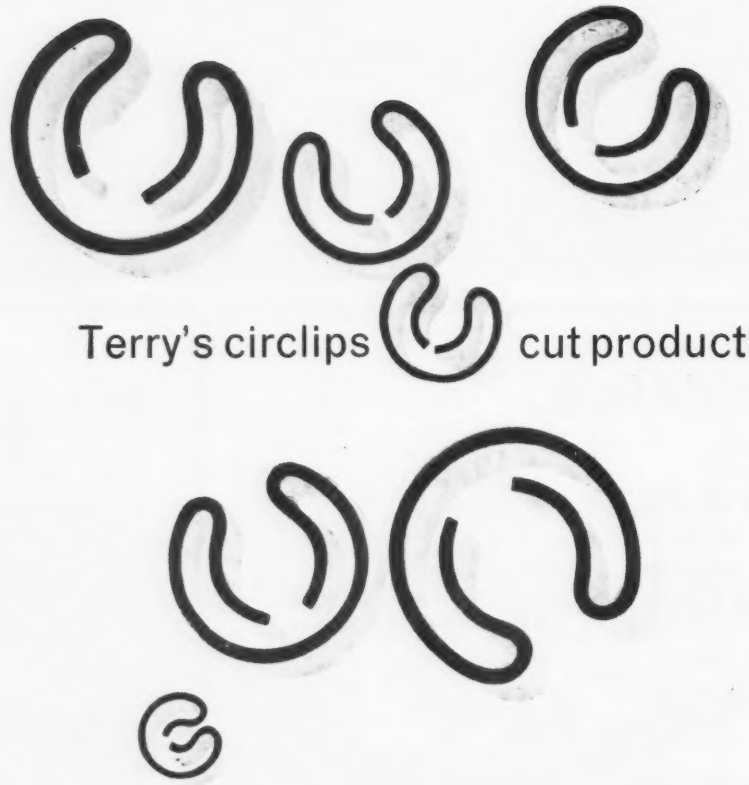
■ swing over bed		
20½"	20½"	26½"
■ centre distance (normal turning) up to		
118"	118"	118"
■ max. copying length		
39½"	39½"	39½"
■ height of centres		
10"	10"	13"
■ main spindle bore		
2½"	2½"	3"
■ no. of speeds		
30	18	18
■ speeds r.p.m.		
9–1800	22.4–1120	11.2–560
	28 –1400	14 –710
	35.5–1800	18 –900
■ motor h.p. up to max.		
26	19	32

Sole British Agents

SYKES

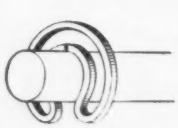
Machine Tool Co. Ltd

Hythe Works, The Hythe
Staines, Middlesex
Telephone
Staines 5076 (3 lines)
Telegrams Sytool Staines



Terry's circlips cut production costs

Delivery from stock in sizes from $\frac{1}{8}$" *to* $\frac{5}{8}$"
Please may we send you samples?



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HERBERT TERRY & SONS LIMITED, REDDITCH, ENGLAND
Famous for springs and presswork for over 100 years

23

come to

LAPOINTE

for better

broaching

Broaching round holes in cross members.

Capacity: 2½/15 tons, stroke: 24/30/36 inches. These machines can be supplied for push, pull or surface broaching.

British Made

The Lapointe Machine Tool Co Ltd

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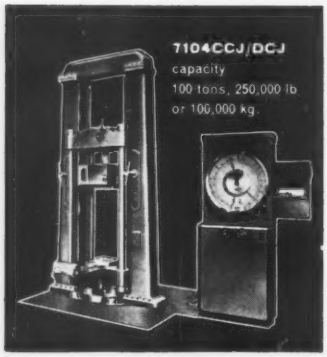
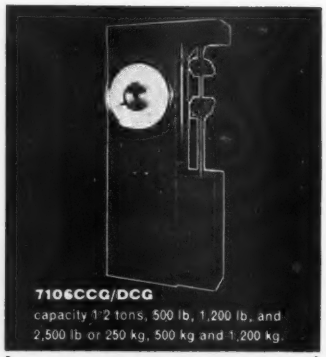
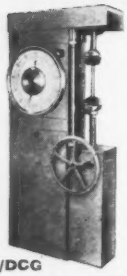


7104CCJ/DCJ
capacity
100 tons, 250,000 lb
or 100,000 kg.

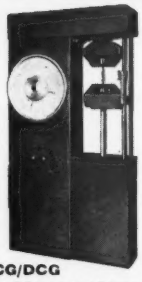
- Avery Universal Testing Machines out-perform all others — cover wide range of loadings; test tensile, compression, hardness, shear and transverse loads to new high standards of accuracy.
- Large, clear Avery dials specially graduated give instantly accurate readings — no mistakes.
- Better Avery instrumentation gives greater versatility and error free operation.
- Avery precision manufacture, high grade materials and quality control ensure lasting accuracy.
- Wide range of Avery accessories suits special needs.
- World-wide Avery servicing keeps machines at peak performance.
- Proved in all conditions throughout the world by leading industries, research organisations and in technical education.



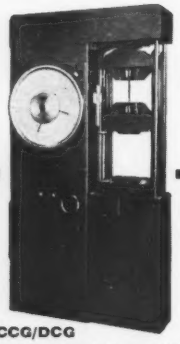
7106CCG/DCG
capacity 1·2 tons, 500 lb, 1,200 lb, and 2,500 lb or 250 kg, 500 kg and 1,200 kg.



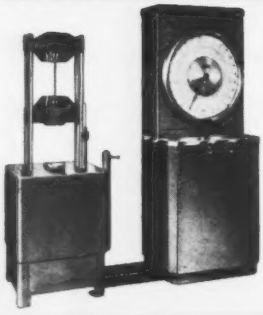
7105CCG/DCG
Capacity 1·2 tons, 500 lb., 1,200 lb., and 2,500 lb., or 250 kg., 500 kg. and 1,200 kg.



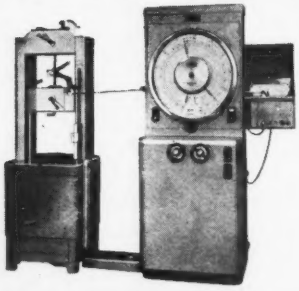
7107CCG/DCG
Capacities 2.5 tons and 5 tons, 5,000 lb. and 12,000 lb., or 2,500 kg. and 5,000 kg.



7108CCG/DCG
Capacity 2.5 tons and 5 tons, 5,000 lb. and 12,000 lb., or 2,500 kg. and 5,000 kg.

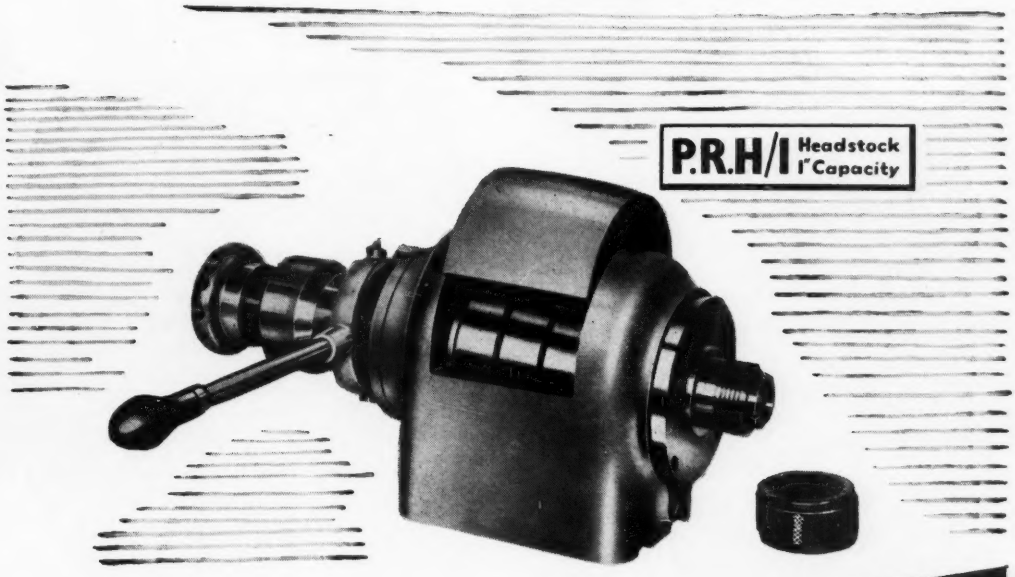


7109CCJ/DCJ
Capacity
10 tons, 25,000 lb.,
or 10,000 kg.



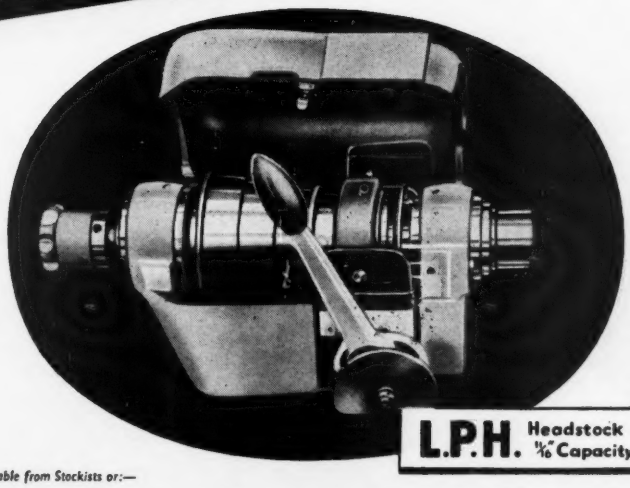
7110CCJ/DCG
Capacity 25 tons and 50 tons, 60,000 lb. and 120,000 lb., or 25,000 kg. and 50,000 kg.

For further details of these and the many other Avery testing machines write to:
Publicity Department, W. & T. Avery, Limited, Birmingham 40.



ADDITIONAL HEADSTOCKS

for the Versatile **Series 'L'** *Lathe....*



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NRP 362

That's the ticket

Look closely at the railway coach you ride in and you will probably find that it features Crompton Parkinson stud welding. Examine the signal gantries it passes and you will certainly come across stud welding again. And, if you were to delve really deeply into the matter, it is more than likely that you would discover it once more on the pit-props in the mine that provided the coal required to provide the electricity which drives the train.

What C.P. stud welding does for the railways it does for industry as a whole — reduces costs, simplifies designs and speeds production. It's a sure way to greater productivity — and a permanent way at that! Do you know all about the advantages of stud welding? If not, we shall be glad to put you on the right lines.

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ELECTRICAL EQUIPMENT
(STUD WELDING) LIMITED

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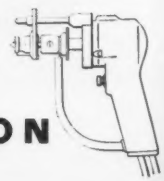

STUD WELDING STEPS UP PRODUCTION

BUTTERLEY

MEEHANITE Regd.

IRON CASTINGS FOR THE MACHINE TOOL INDUSTRY

Two examples of Butterley castings for machine tools—one a press body, the other an arm casting for a radial drill. In each case a first class casting is required with rigidity, soundness and good machining properties.

The press bodies are cast in a Grade C Meehanite with tensile properties in the region of 18/20 tons per square inch. Weight 1,232 lb.

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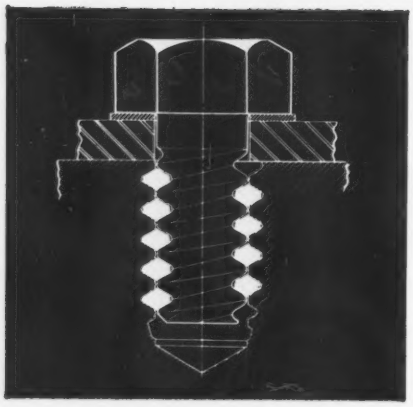

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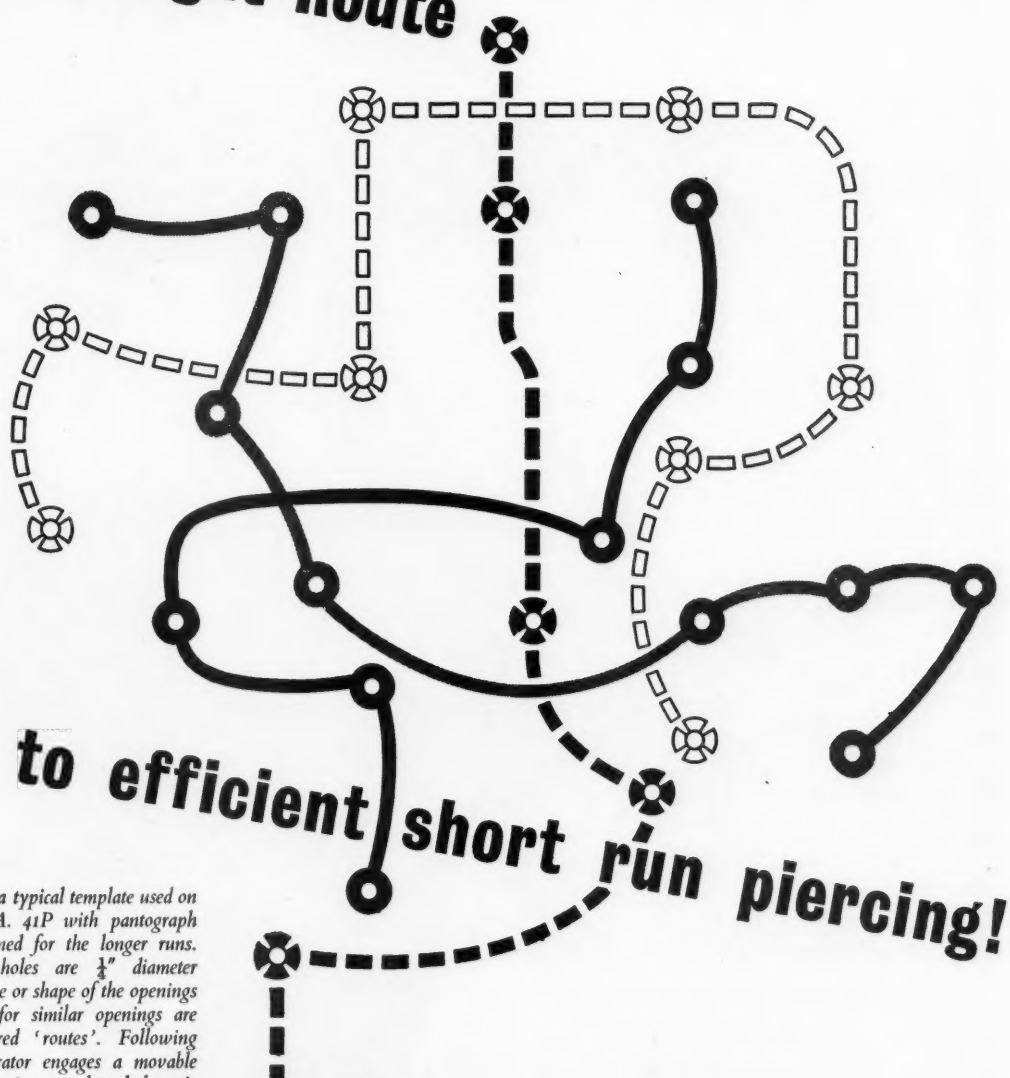

to efficient short run piercing!

This is a section of a typical template used on the Wiedemann RA. 41P with pantograph table specially designed for the longer runs. All the template holes are ¼" diameter irrespective of the size or shape of the openings in the job. Holes for similar openings are connected by coloured 'routes'. Following each route the operator engages a movable stylus in each successive template hole. As the stylus is moved the work follows. When the last hole is reached the operator indexes the turret to the next position and starts on the next 'route' ensuring the least number of work and turret movements.

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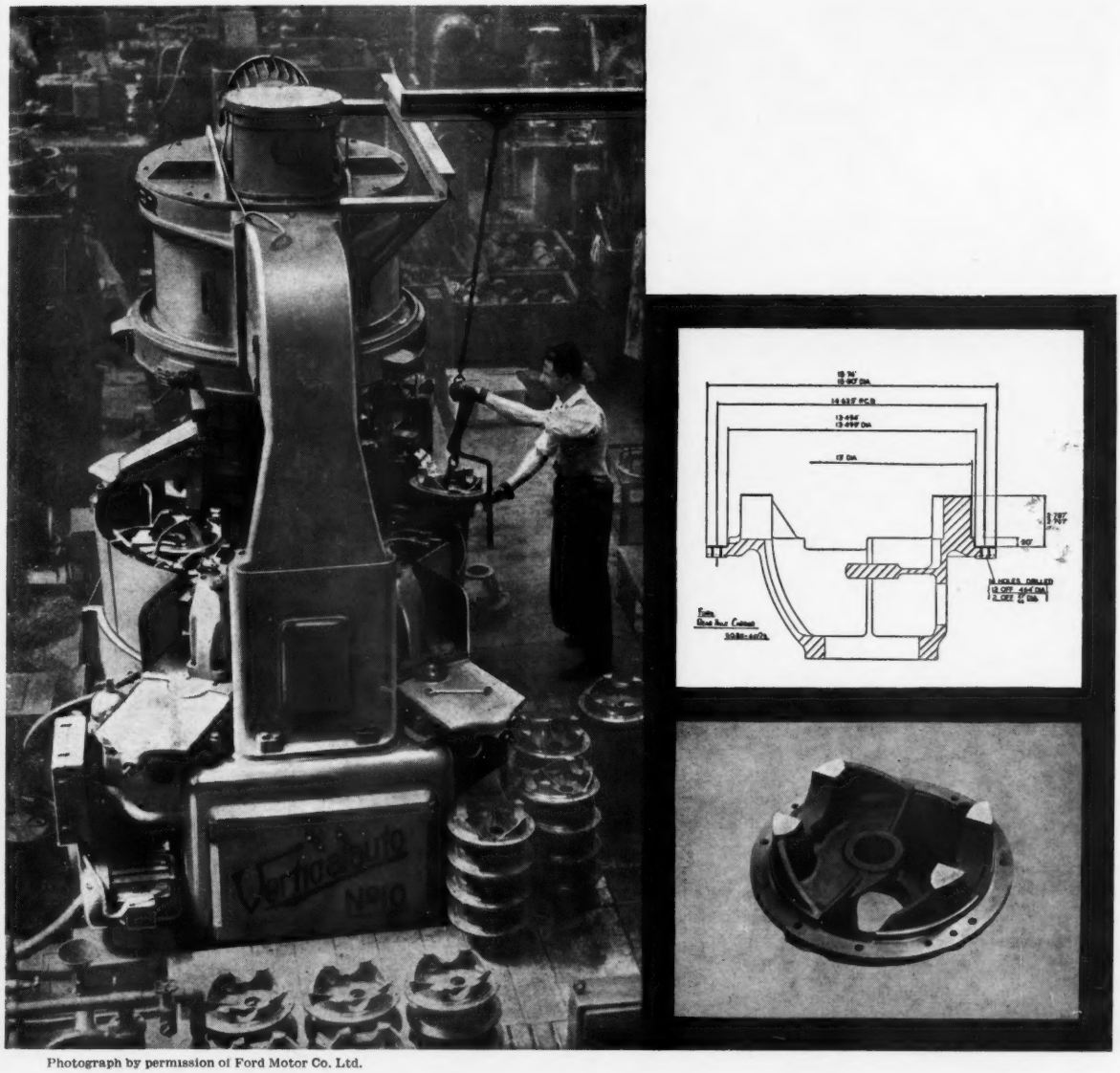

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Machining of Ford rear axle carriers

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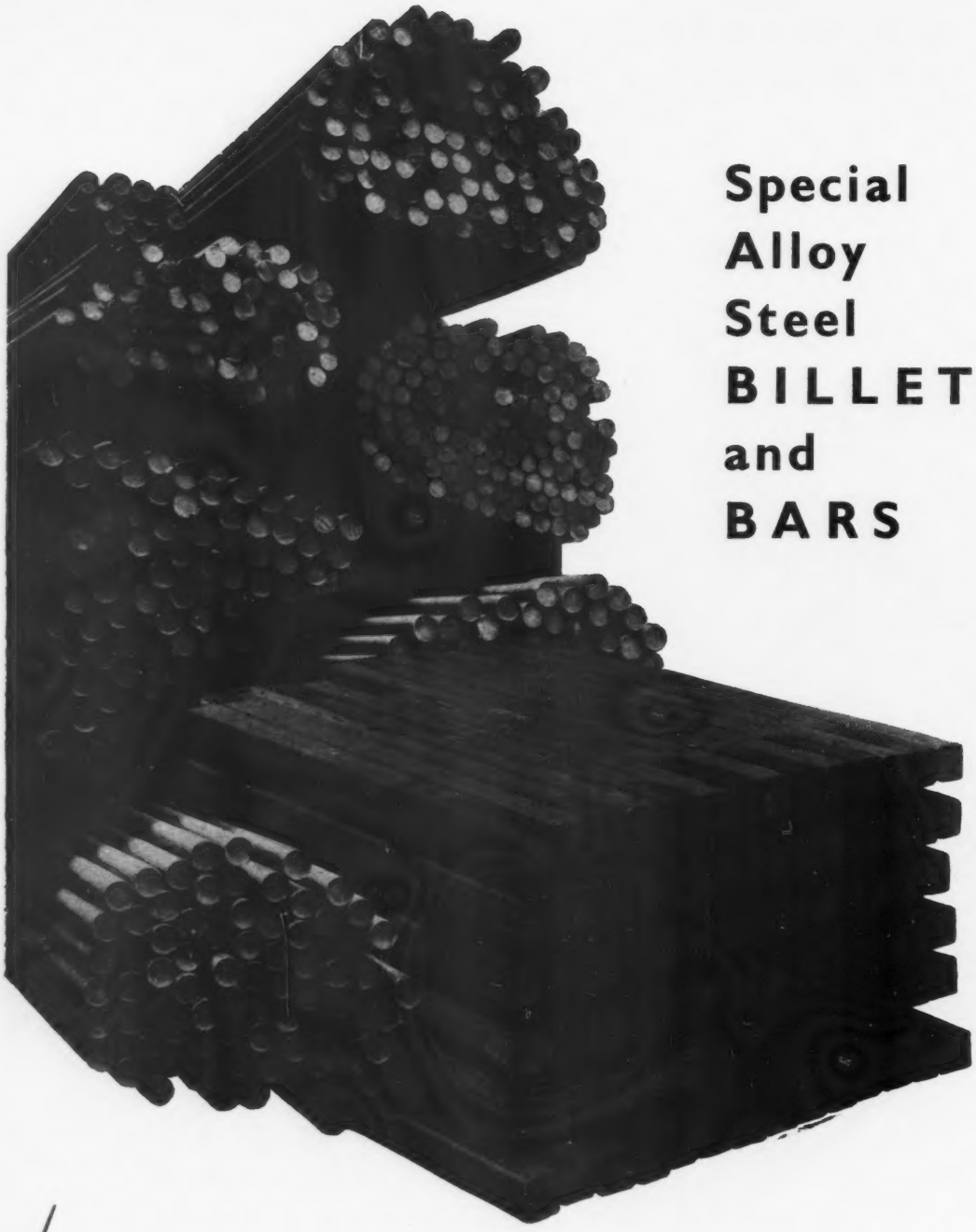

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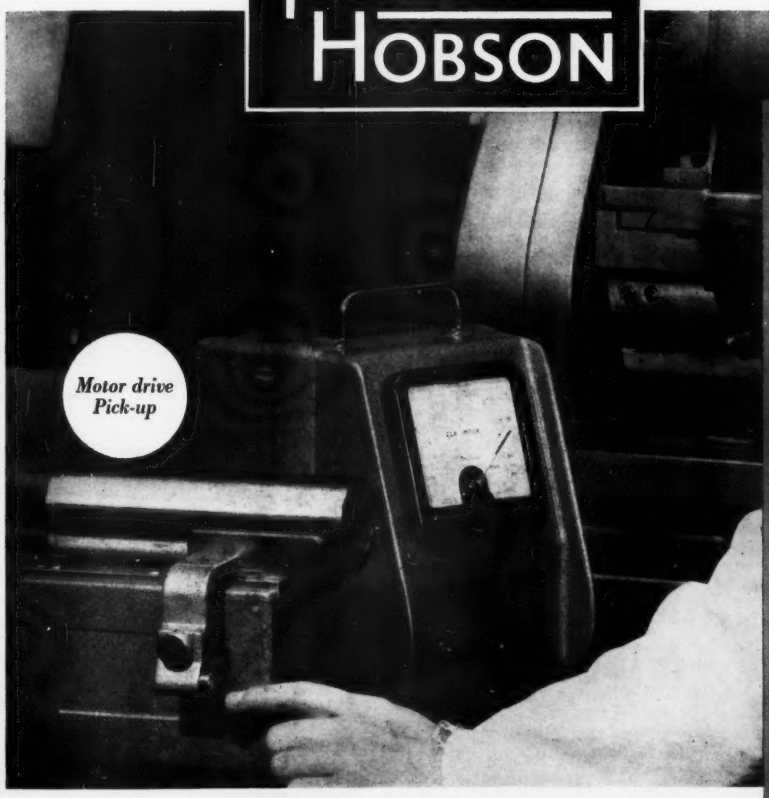

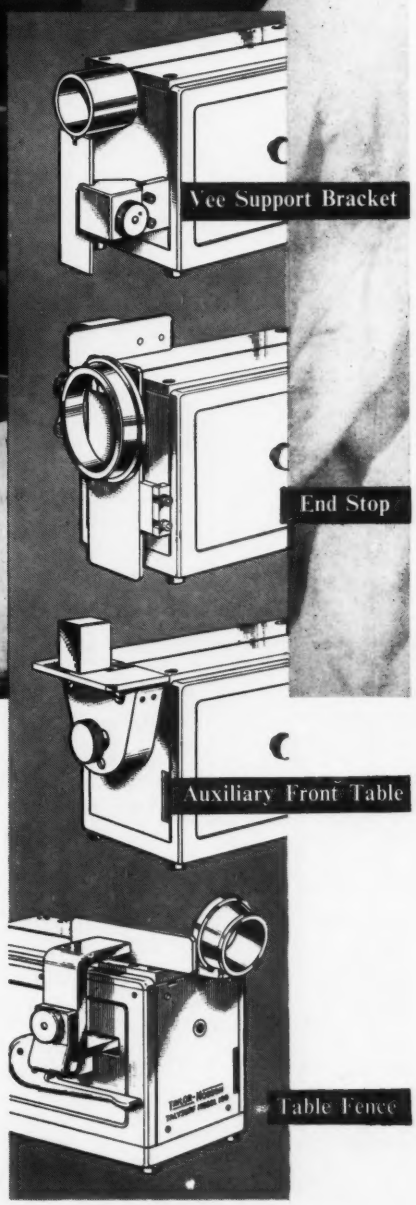

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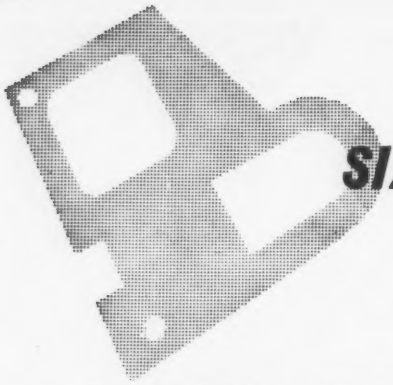

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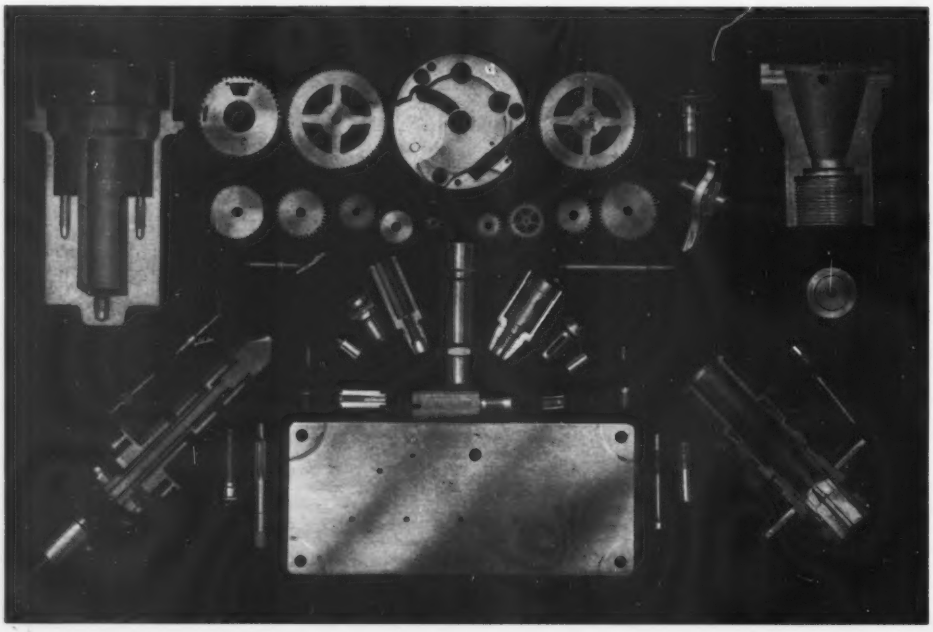

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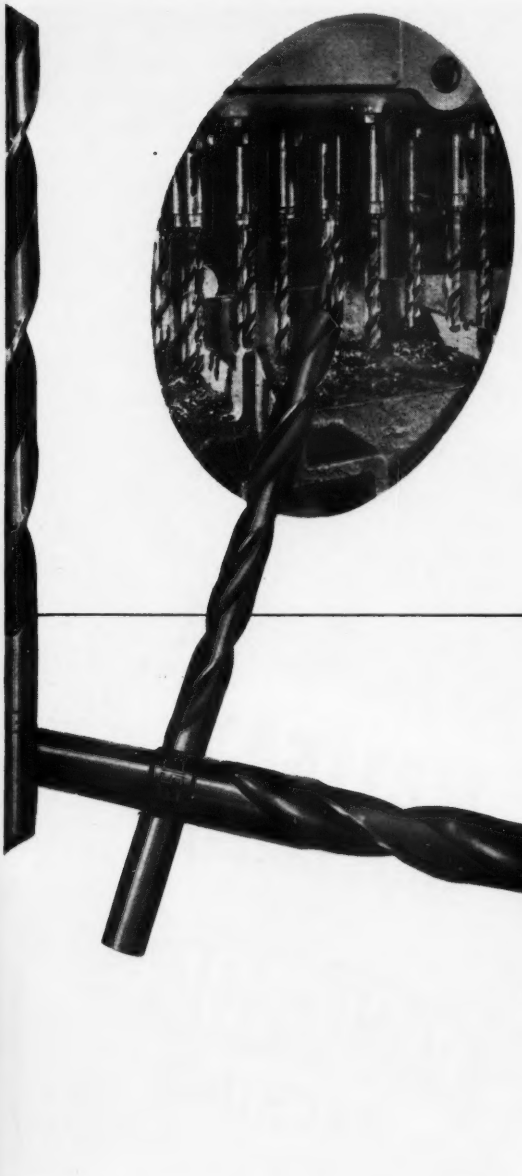

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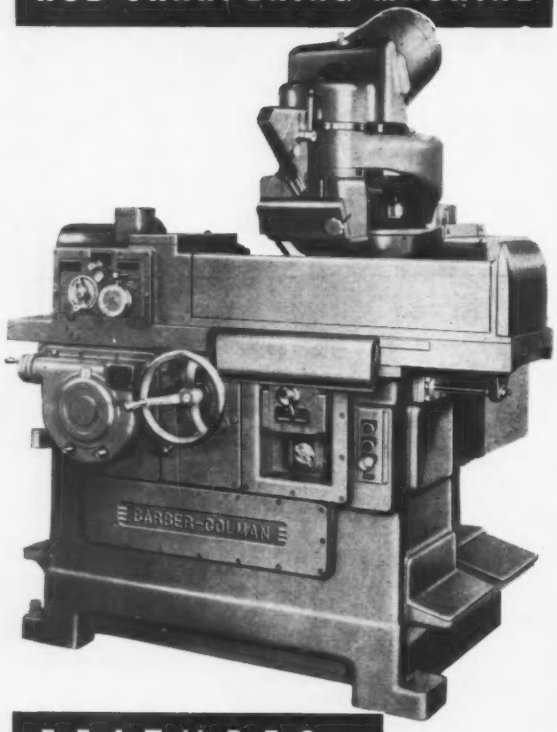

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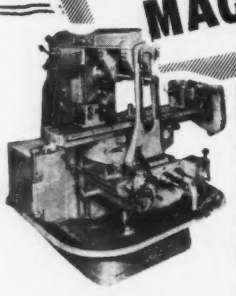

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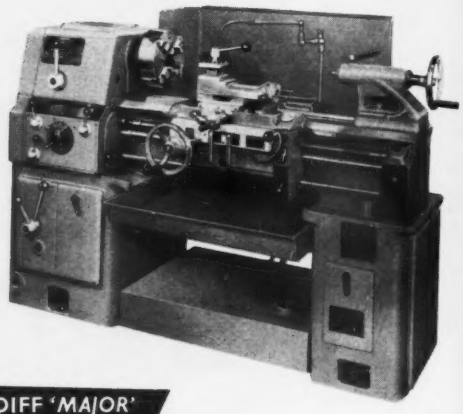

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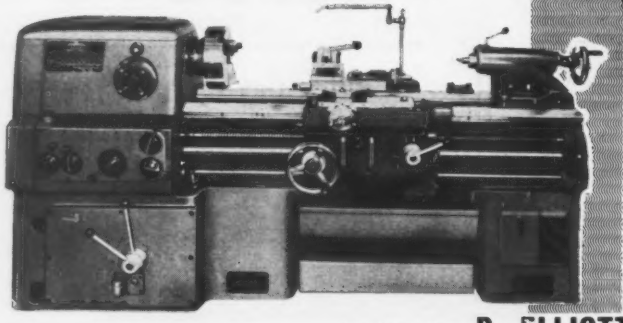

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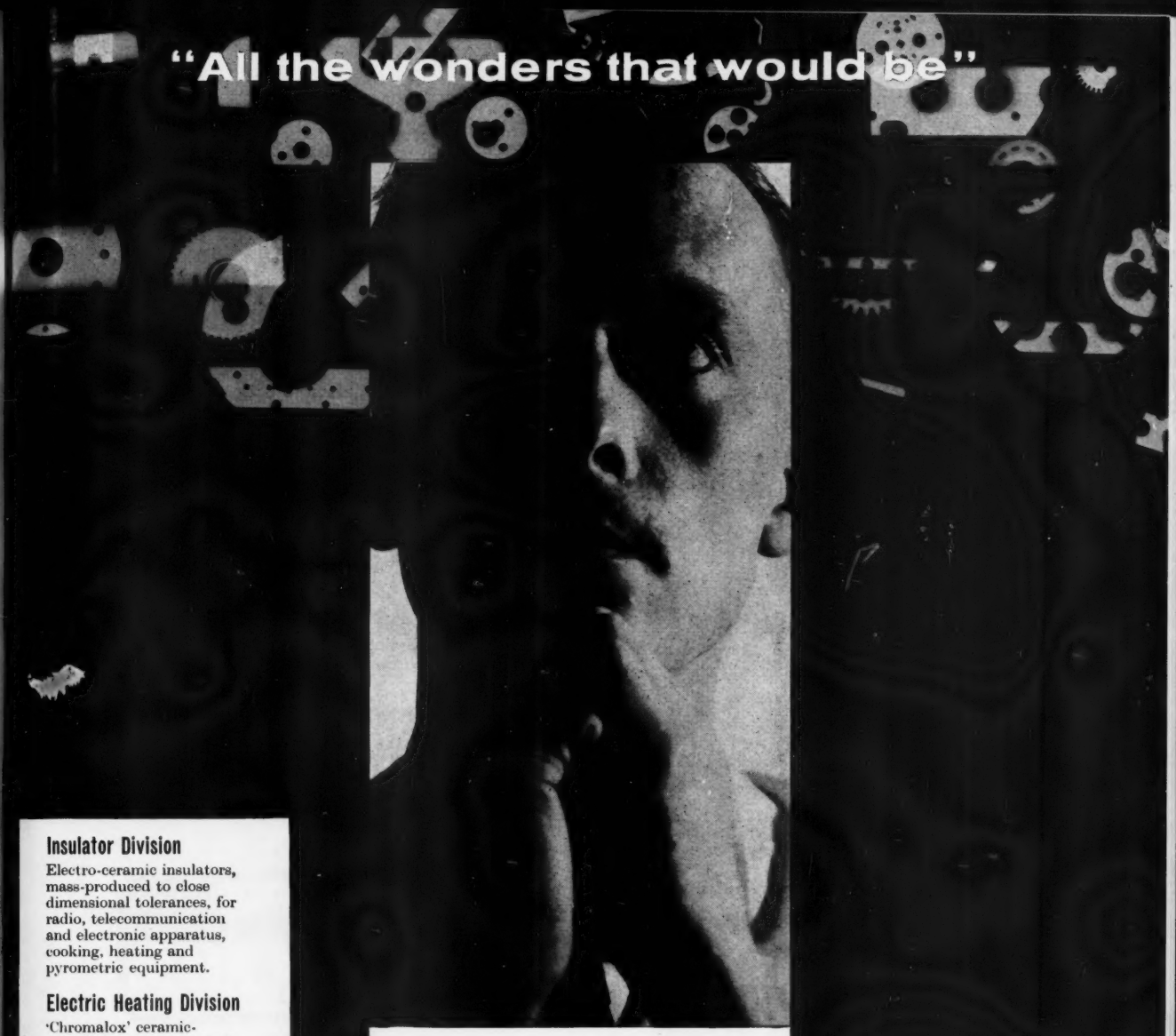

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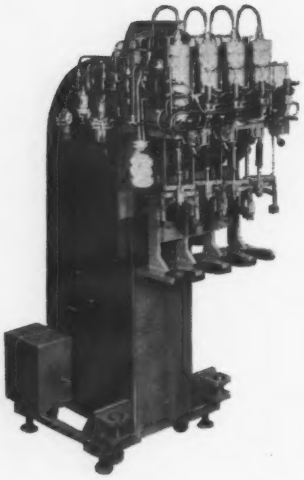

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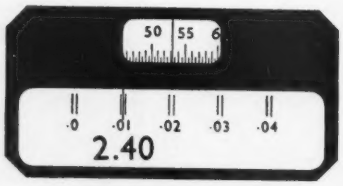

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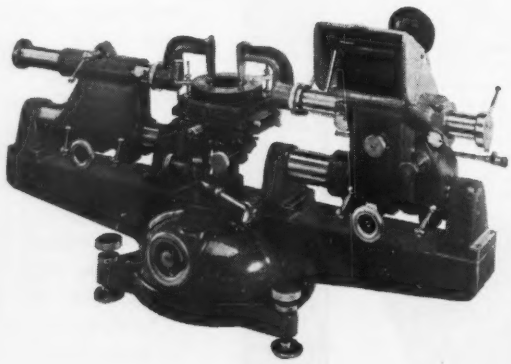

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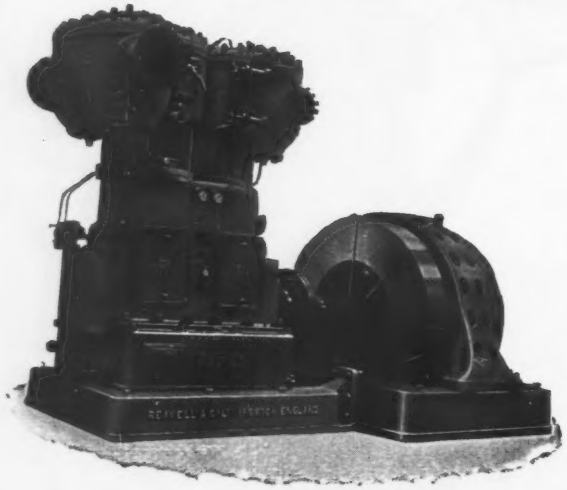

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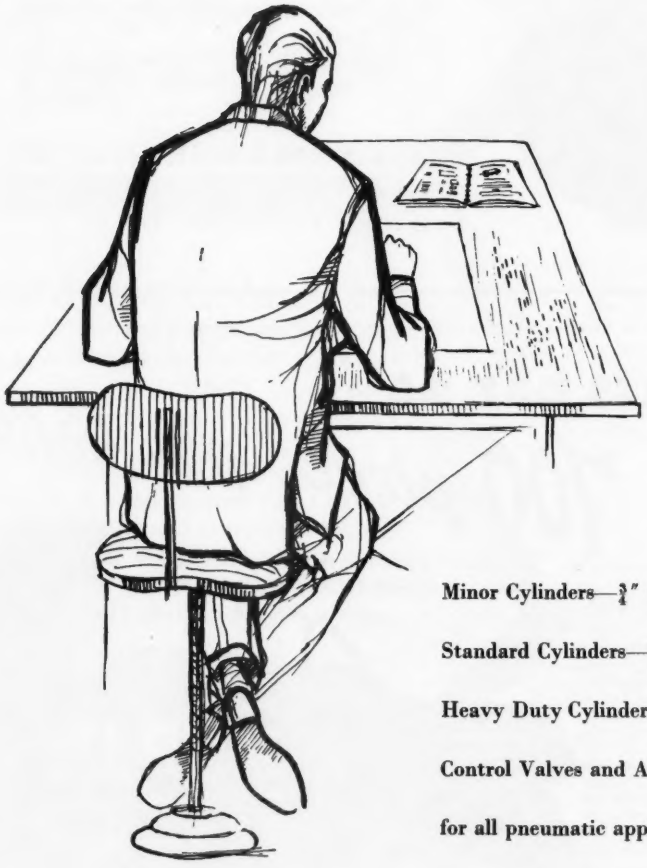

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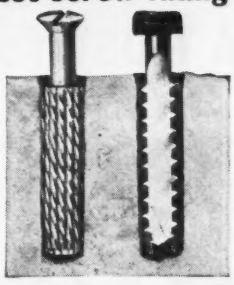

Rawlplugs make firm screw fixings in brick, tiles, cement, stone, etc., in a fraction of the time taken by any other method. Drill the material, insert the Rawlplug, screw up—it's as simple as that! Safe, permanent, and completely reliable in any climate. For all screw sizes up to ¾" coach screws.

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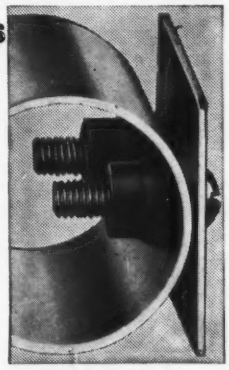

For almost impossible jobs use the Rawlnut. (You can even make a fixing to a pipe). The tapped nut in the end of the rubber bush is drawn up to the reverse face of the material by turning the screw. The result is an airtight, watertight, vibration-proof fixing of enormous strength. For thin plastic, metal, wallboard and hollow pot, etc., it is invaluable.

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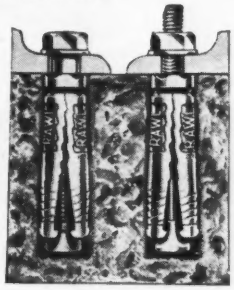

For light or heavy bolting jobs, no other method even *begins* to approach Rawlbolts for strength, ease and speed. Rawlbolts are a *dry* fixing, they grip at once by expansion—no cold chiselling, no grouting in, no waiting for cement to harden. In all bolt diameters up to 1" in either loose bolt or bolt projecting types.

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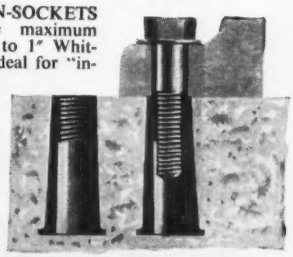

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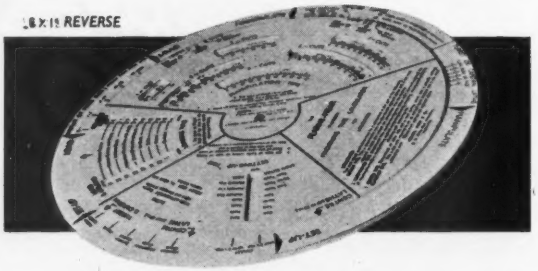

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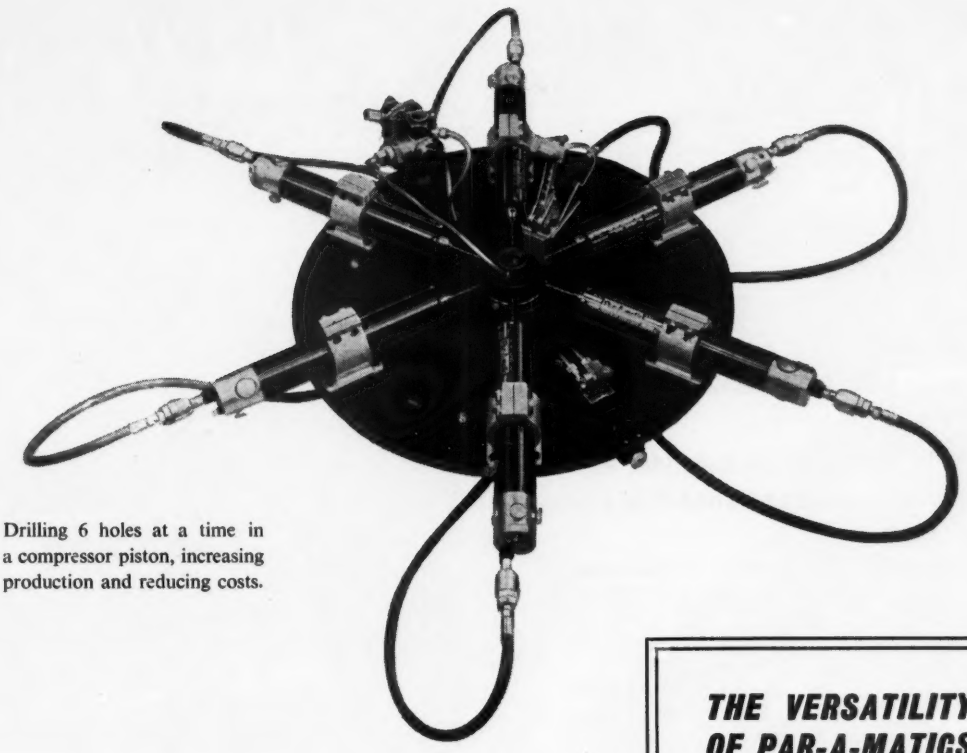

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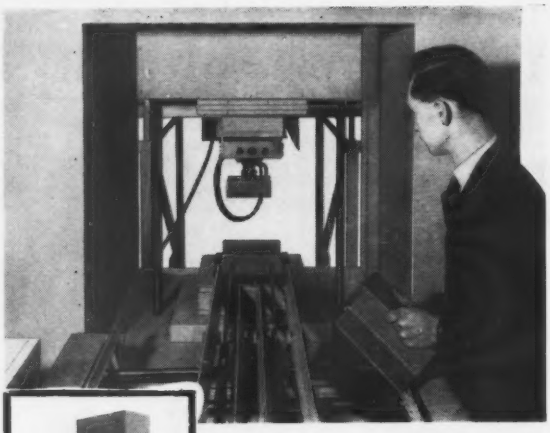

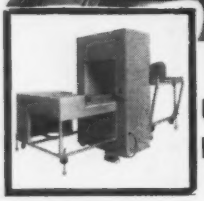

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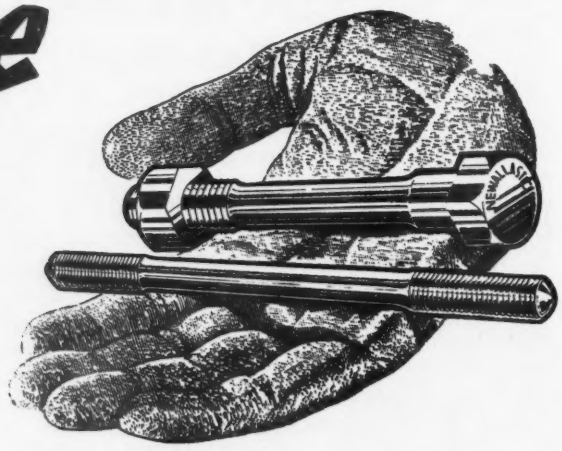

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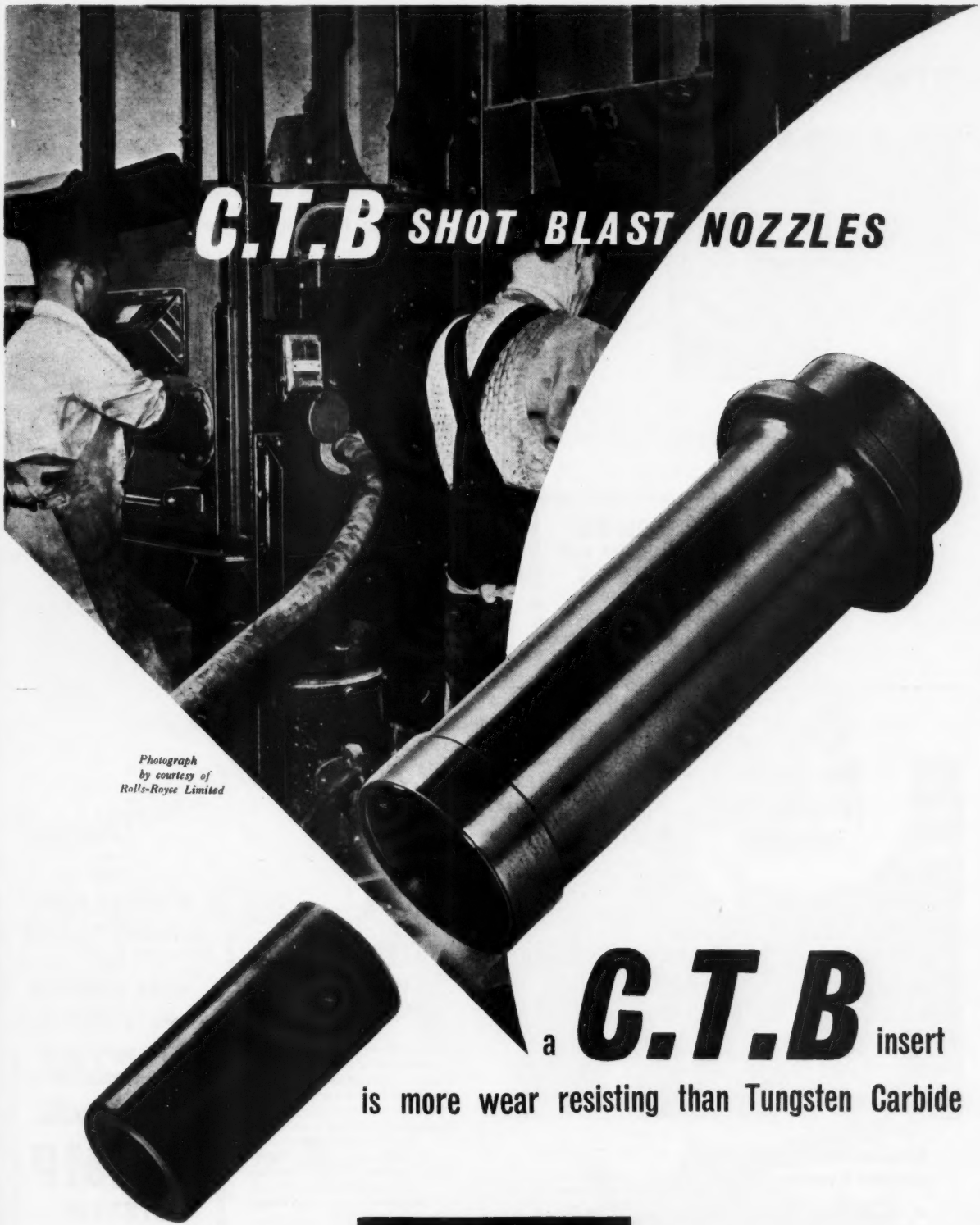

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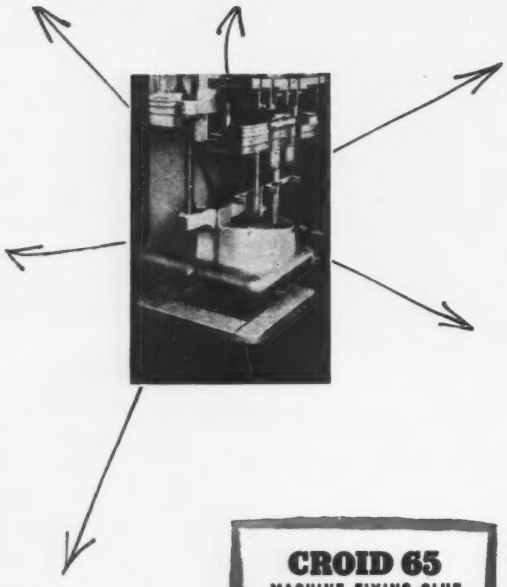

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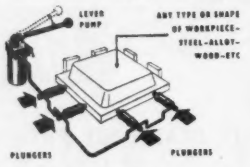

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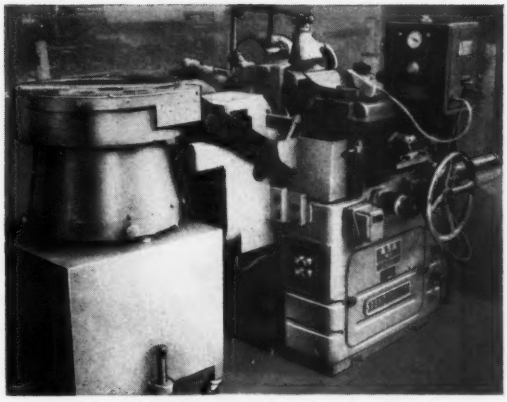

No. 4 machine equipped for automatic sizing-control and automatic infeed. Vibratory type hopper. Special bolts 7/16" × 2⅞"(11 mm × 73 mm)long are ground to a tolerance of 0.0005"(0.012 mm) Production : 700 bolts per hour. Sizing-control incorporates automatic grinding wheel head feed-compensation.

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Width of wheels :	4" (101 mm) or 5" (127 mm)
Main motor :	10 h.p.

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Work diameter :	1/8" to 6½" (3.17 to 167 mm)
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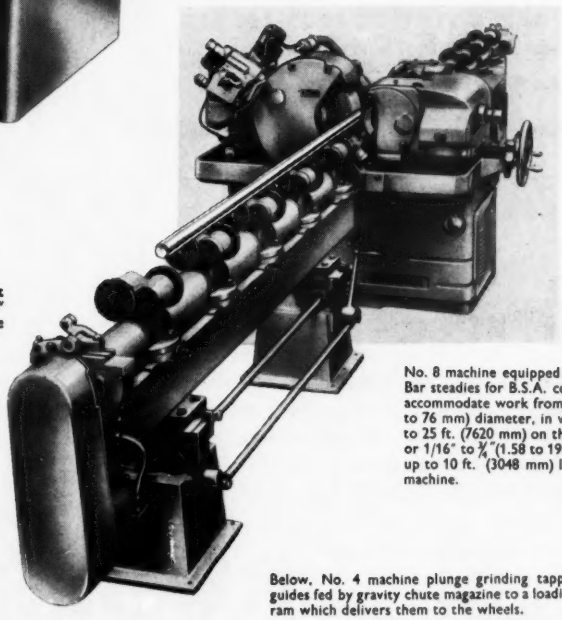
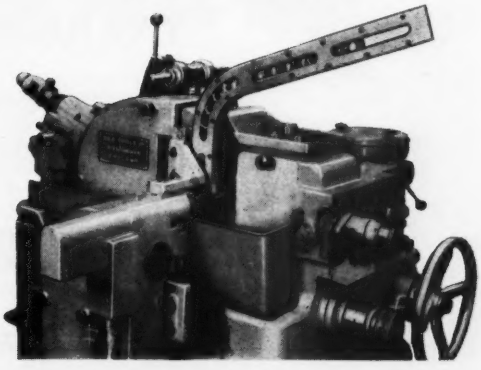
*(With special equipment work down to 0.010" (0.254 mm) dia. can be accommodated).



No. 8 machine equipped for bar grinding. Bar steadies for B.S.A. centreless grinders accommodate work from 1/16" to 3" (1.58 to 76 mm) diameter, in various lengths up to 25 ft. (7620 mm) on the No. 8 machine, or 1/16" to ¾" (1.58 to 19.05 mm) diameter up to 10 ft. (3048 mm) long on the No. 4 machine.

Below, No. 4 machine plunge grinding tappet guides fed by gravity chute magazine to a loading ram which delivers them to the wheels.



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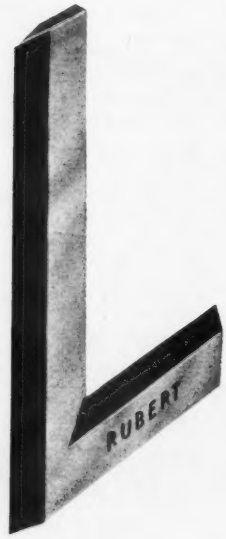

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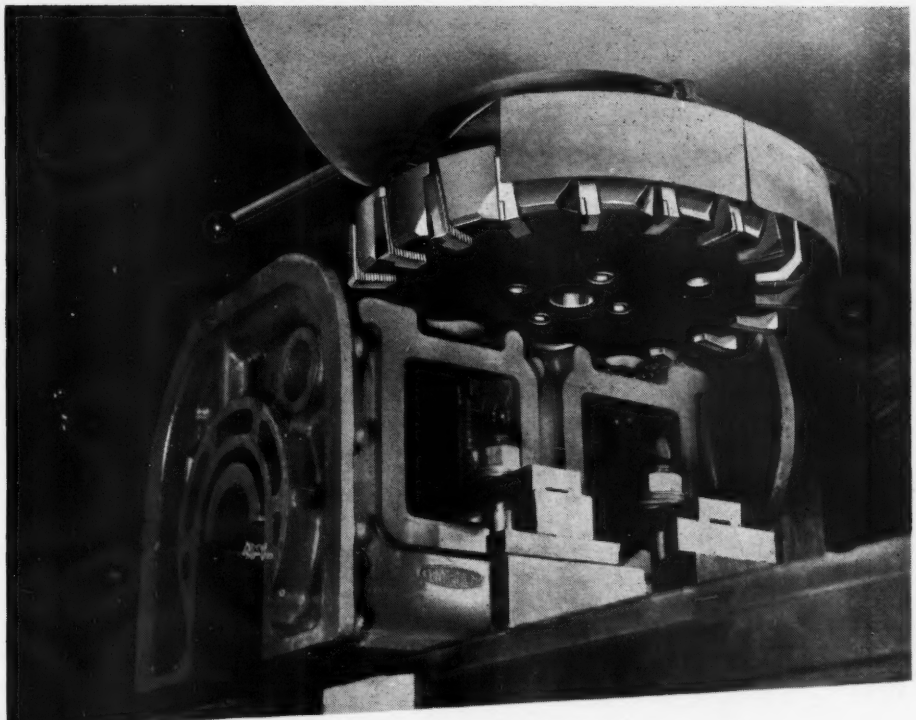

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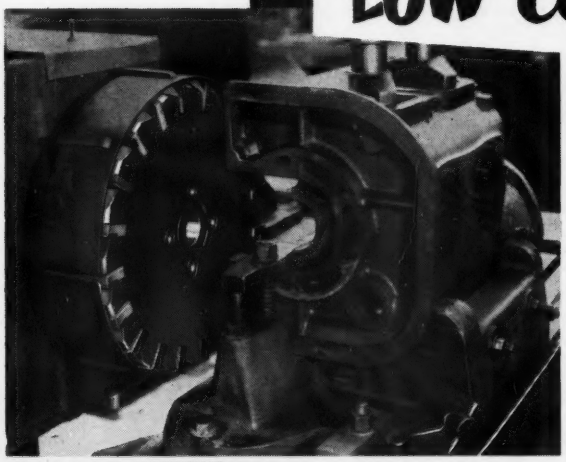

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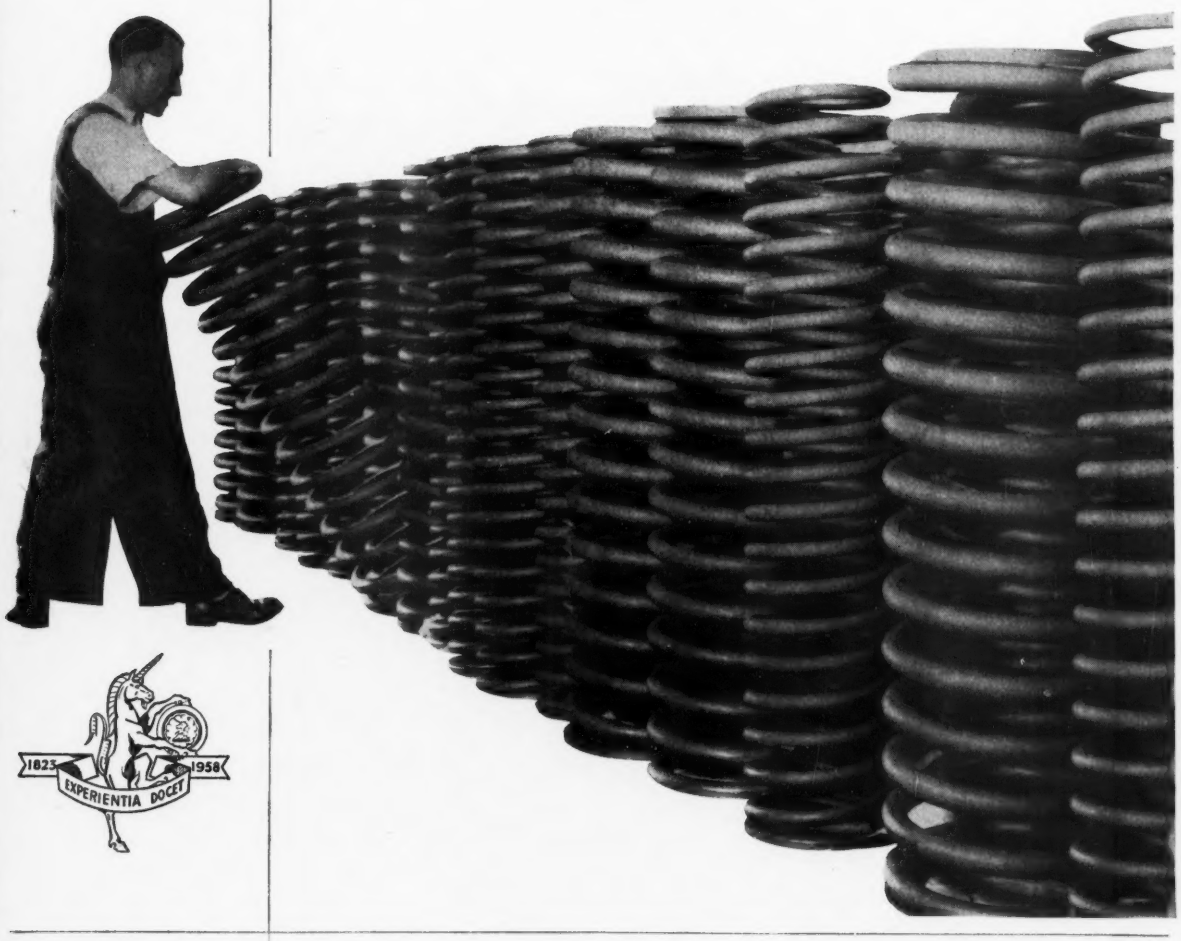

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